PB82-158973

Decision-Maker's Guide in Water Supply Management

Culp/Wesner/Culp
El Dorado Hills, CA

Prepared for

Environmental Protection Agency
Washington, DC

Nov 79

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO.

2.

3. RECIPIENT'S ACCESSION NO.
PB82 158973

4. TITLE AND SUBTITLE
Decision-Maker's Guide in Water Supply Management

5. REPORT DATE
November 1979

6. PERFORMING ORGANIZATION CODE
036036

7. AUTHOR(S)
Culp/Wesner/Culp

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Culp/Wesner/Culp
Clean Water Consultants
Box 40
El Dorado Hills, CA 95630

10. PROGRAM ELEMENT NO.
A63C2B

11. CONTRACT/GRANT NO.
WA-78-A015

12. SPONSORING AGENCY NAME AND ADDRESS
Environmental Protection Agency
Office of Drinking Water (WH-550)
401 M Street, S.W.
Washington, D.C. 20460

13. TYPE OF REPORT AND PERIOD COVERED
Final Report

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Under the Safe Drinking Water Act, water utilities are responsible for more than direct operation and maintenance of their systems. Other responsibilities include monitoring, public notification for violations of regulations, record keeping, and provision of necessary facilities supplies, personnel and operating vigilance to assure continuous delivery of safe drinking water. In addition, utilities must demonstrate consistent compliance with the requirements of the primary drinking water regulations established under the Safe Drinking Water Act.

Water supply management is noticeably most complex for today's public officials. This quide provides information to help define the scope of problems faced by water utility managers and presents information to assist in the resolution of these problems. It provides an overview of the key issues concerning water supply and suggests avenues for addressing detailed, specific questions throught recommended reference lists and the use of consultants.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Water supply Water Treatment Decision Making Maintenance Management Financial Management Potable Water Public Utilities	Water Distribution Water Production Water Quality		0609 Hygiene & Sanitation 1302 Civil Engineering

18. DISTRIBUTION STATEMENT

19. SECURITY CLASS *(This Report)*

20. SECURITY CLASS *(This page)*

21. NO. OF PAGES

22. PRICE

EPA Form 2220-1 (9-73)

PB82-158973

FINAL REPORT

DECISION-MAKERS' GUIDE IN WATER SUPPLY MANAGEMENT

PREPARED BY

CULP / WESNER / CULP — CLEAN WATER CONSULTANTS
BOX 40, EL DORADO HILLS, CA 95630

PROJECT OFFICER
HUGH HANSON
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

November, 1979

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

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ACKNOWLEDGMENT & DISCLAIMER

This guide was prepared by Culp/Wesner/Culp, Clean Water Consultants (CWC), of El Dorado Hills, California, with Dr. William F. Owen and Justine A. Faisst as authors and Russell L. Culp as editor. All work was done under contract to the U.S. EPA. CWC is solely responsible for the contents of the guide.

A Validation Panel of nine water works people, public officials, and citizens assisted in preparation of the guide by reviewing and commenting on the original outline for the report and on the original draft of the final report. However, the Panel had no control over the content of the final report, and CWC alone is responsible for it. Participation by Panel members does not constitute their approval or endorsement of the manual or its contents. Validation Panel members are listed below:

Reese Riddiough
Public Works Director
City of Santa Maria,
California

John O. Nelson
General Manager
North Marin County
Water District
P.O. Box 146
Novato, CA 94947

Marshall Haney
Utilities Director
P.O. Box 309
Richardson, TX 75080

David W. Callahan
Assistant Manager
South Tahoe Public
Utility District
P.O. Box AU
South Lake Tahoe, CA 95705

Mrs. Arlis Ungar
League of Women Voters of Calif.
517 Silverado Drive
Lafayette, CA 94540

Robert Lee
General Manager
Medford Water Commission
City Hall
Medford, Oregon 97501

Richard Pelton
Water Superintendent
P.O. Box 1038
Topeka, Kansas 66601

Sat Tamarabuchi
Manager of Planning
Irvine Ranch Water District
P.O. Box D-1
Irvine, CA 92716

The ninth member of the Panel and Project Officer for EPA was Hugh Hanson, Office of Drinking Water.

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APPENDIX F: Delete

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1. Page 1-1, question 6: Change to: "See pages 1-3 to 1-7."
2. Page 1-5, Paragraph 1: Add the underlined words: "... an additional two year period for exemptions for systems entering........"

Section 4

1. Page 4-1, paragraph 1: Change item 3 to read "... maintained?" (See pg. 4-3, Table 4-1)

Section 5

1. Tab: Change "Rational" to "Rationale".
2. Page 5-1, paragraph 3: In item 2 delete the phrase in parenthesis.
3. Page 5-1, paragraph 3: In item 4 replace the phrase in parenthesis with : "(See the National Academy of Sciences Report; Drinking Water and Health)".
4. Page 5-2, paragraph 2: Change sentence four to read: "The NIPDWR were published in the Federal Register (See Appendix A)".
5. Page 5-2, paragraph 3: Delete: "The revisions .... sometime in 1980".
6. Page 5-3, last paragraph: In the fourth and fifth sentences change "January 1, 1981" and "January 1, 1983" to "January 1, 1984" and "January 1, 1986" respectively.

7. Page 5-4, fourth paragraph: Change to read as follows: "Details on health effects and the basis for the standards are published in EPA publication 570/9-76-003 entitled: National Interim Primary Drinking Water Regulations (NTIS #PB 267-630) and also in the 1973 Report of the EPA Advisory Committee on the Revision and Application of the Drinking Water Standards".
8. Page 5-4, fifth paragraph, fourth sentence: Delete "(as indicated in Appendix F)".
9. Page 5-7, References. Add: "Drinking Water and Health, Volumes I,II, & III, National Academy of Sciences, 2101 Constitution Ave. Washington, D.C. 20418.

Section 8

1. Page 8-2: first sentence: Delete: "Detailed discussions....of this guide".
2. Page 8-5, Sentence 1: Change as follows: "...regulatory activity (44 FR 63624, November 29, 1979) of EPA....."
3. Page 8-5, paragraph 4: Change "larium" to "barium".

Section 12

1. Page 12-1, paragraph 2: In item 3 replace the contents of the parenthesis with: "(See Appendix A)"
2. Page 12-1, paragraph 3 delete: "As noted i Table 12-1, ...distribution system".

3. Page 12-2, eliminate Table 12-1.

Section 15

1. Page 15-1, last sentence: Replace the last sentence with the statement: "Many of these programs are no longer funded or are not funded to the degree they were. Individuals should check with these agencies to find out more about the financial assistance programs."

DECISION-MAKERS' GUIDE
IN WATER SUPPLY MANAGEMENT

INTRODUCTION

Today's decision makers in the drinking water field have a unique opportunity to improve the quality and safety of public water supplies. The findings of the U.S. Public Health Service Community Water Supply Study in 1970 as to the deficiencies in water systems were surprising to laymen and professionals alike, and marked the start of an increased public concern over drinking water quality. The Public Health Service report showed that approximately 17 percent of all existing public water supplies failed to meet one or more of the mandatory quality standards; 25 percent did not meet one or more of the recommended quality standards; more than 50 percent had major deficiencies in supply, storage, or distribution facilities; 12 percent failed to meet the bacteriological quality standards; and 90 percent had no programs for control of cross connection hazards. There are also serious deficiencies in training programs and compensation schedules for water works employees.

The General Accounting Office (GAO) reached similar conclusions after reviewing six State water supply programs. The GAO report stated that "potentially dangerous water was being delivered to some customers, particularly by small water supply systems serving populations of 5,000 or less."

Sufficient questions have arisen regarding water safety to concern the public and to give impetus to adoption of the Safe Drinking Water Act of 1974 (SDWA: PL 93-523). For details of the SDWA, please refer to Appendix A of this report.

Under the SDWA, water utilities have several responsibilities beyond direct operation and maintenance including the following: monitoring, public notification for violations of the SDWA, and record keeping. Water utilities must provide the necessary facilities, personnel, and operating vigilance to assure continuous delivery of safe water which consistently meets the requirements of the National Interim Primary Drinking Water Regulations, established under the SDWA.

Water supply management is noticeably more complex for today's public officials, especially in small communities. Accordingly, the purpose of this guide is to provide information that will help define the scope of problems facing water utility management and assist in their solution. The manual presents an overview of the key issues concerning water supply and suggests the means for addressing detailed, specific questions related to these issues through recommended reference lists and use of consultants.

Protection of the quality and safety of public water supplies is now undergoing rapid development and change. Water works operators are faced with many new and complex problems, but they have the advantage of new technology to solve these problems.

In the past water treatment has developed partially as an art as well as a science. The water industry has frequently failed to utilize fully known, proven methods for solving many water problems, and has been slow to adapt new scientific ideas and principles to water works practice. There now exists a great backlog of scientific and engineering data which might be used to the benefit of the public by application of innovative solutions to today's water problems.

As examples, over the past fifteen years safe rates for filter operation have been increased from 2 gpm/sf (gallons per minute per square foot) to 5 gpm/sf by replacement of single media (sand or coal) filters with dual media (sand and coal) or mixed media (sand, coal, and garnet) filters. This has cut the cost of filtration, and greatly increased the efficiency and reliability of the filtration process.

Shallow depth sedimentation theory has been applied to water works practice to bring high rate settling into use through development of tube settlers. These devices are now marketed by several manufacturers. They save space and cut settling costs. The space saving makes possible the production of factory fabricated treatment plants of greater capacity.

Granular activated carbon has been introduced as a new and very effective means of taste and odor control for many public drinking water supplies. On-site and off-site reactivation of granular activated carbon for reuse is now making possible the application of carbon to remove a broad range of potentially harmful trace organic substances from water supplies.

Discovery of the production of undesirable by-products during chlorination in water treatment has led to development of means for minimizing such by-product formation through proper selection of points for proper chlorine application. This has also led to consideration of pre-oxidation or disinfection with ozone, chlorine dioxide, or other substances.

There have also been recent improvements in methods for disposing of water treatment sludges and for reclamation and reuse of water treatment chemicals.

Some of the most dramatic improvements in water supply methods are new laboratory and monitoring techniques. The sensitivity and detection limits of many tests have been greatly increased, and the use of instruments and computers for process control and monitoring has been greatly extended.

These new concepts in water purification can be applied to remedy a wide variety of conditions which are of current public concern. They can be used to treat water supplies which are receiving greatly increased pollutional loads of domestic wastes and new complex chemical wastes from industrial and agricultural operations. They can be used to remove pesticides, herbicides, some heavy metals, and other substances which are objectionable even when present only in trace amounts. They can remove taste and odor from water and eliminate the hazards involved when unpalatable tap water drives consumers to the purchase of bottled water at much higher cost. These methods can be used to treat runoff from watersheds which were once considered to be "protected," but which are now subject to development or to the pollutional threats posed by the widespread use of trail

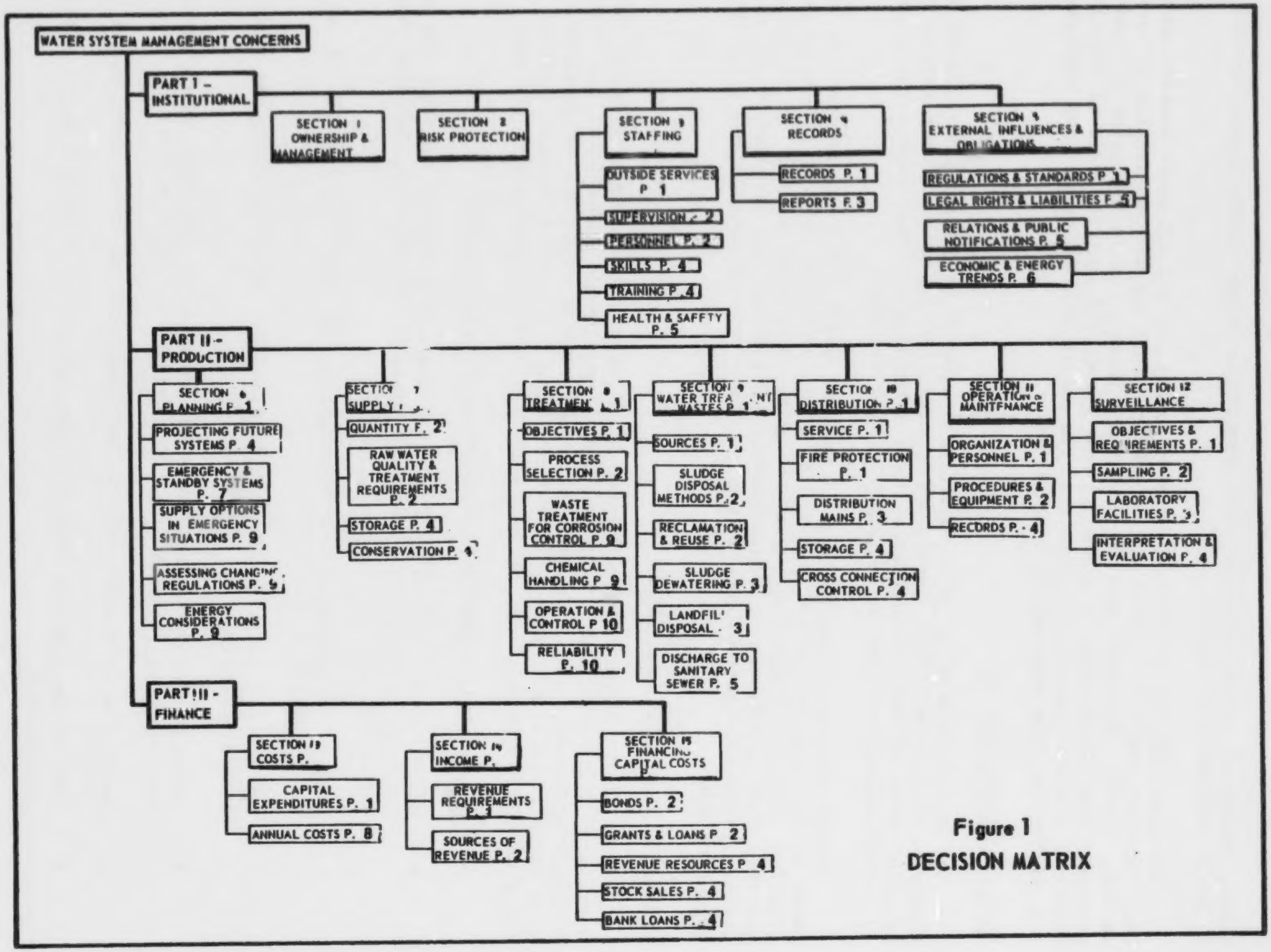
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Figure 1
DECISION MATRIX

bikes, four-wheel drive vehicles, and snowmobiles which enable people to reach formerly inaccessible areas.

The means are now at hand to solve virtually any and all water quality problems. However, there is a great lag in the practical use and application of these methods. A great deal more must be done. Many recently perfected water treatment processes must be included in plans for new plants and must be added to existing plants if the full potential benefits to the public from scientific and engineering progress in this area are to be realized.

Decision Making Process

The decisions made by water utility management encompass a wide range of economic, social, political, legal, and technological questions. Furthermore, the specific concerns vary considerably among communities - thus each organization encounters unique problems or decisions to be resolved.

Through continuous surveillance, a manager identifies specific problems and needs of his organization and anticipates future areas of concern. These include questions concerning personnel, administrative, and legal as well as technical matters. Then, any system or organizational deficiencies are resolved by defining the available alternatives and making the changes that most economically meet community needs.

Water System Management Concerns

Water utility management addresses three major areas: institutional, production, and finance. Some of the prominent concerns in these areas are illustrated diagrammatically in Figure 1, which corresponds to a table of contents for this manual. There is a strong interaction among the various factors involved in water system management that influences the ultimate decision-making process.

Some of the utility manager's most pressing concerns are:

- unfamiliarity with current EPA and State regulations and what EPA and State expect from him under the present and impending Drinking Water Regulations
- lack of knowledge of new technologies and what they can do to solve water problems
- how to hire a qualified consultant and how to avoid hiring an unqualified consultant
- inadequate compensation levels for water works personnel which prevent him from attracting, hiring, or retaining qualified workers
- resistance to change, both by the public and the water works industry
- lack of information regarding the methods of financing major capital improvements

- local political concerns

- how to replace lost ad valorem tax funds with new revenues

The fundamental force governing most management decisions is finance. A successful administration, public or private, is based on sound economic policy. The cost of operating, maintaining, and improving a facility must be balanced by revenues. As with any business, this entails satisfactory service at an acceptable price. However, economics of water supply are controlled by institutional and production concerns. Institutional factors such as rate commissions and surveillance by state agencies are often the most important. This is especially true since passage of the SDWA. Legal responsibilities and regulations have increased and, correspondingly, many communities have had to reassess their organizational structure.

Obviously the key to meeting the new regulations and satisfying public demand for better water lies in the production aspects of potable water supply. Notable areas that require additional attention in many systems, as a result of SDWA, include: treatment for meeting specific water quality goals, surveillance to ensure these goals are met, and cross connection control to minimize potential contamination during distribution, and a revenue base sufficient to insure continued viability of the water utility.

Organization and Use of the Decision-Makers' Guide

This Decision-Makers' Guide is intended as a quick referencing system for addressing the key issues of water utility management, particularly for water systems serving 5,000 to 75,000 persons. Smaller systems may need assistance from legal, financial, and engineering consultants in addition to that provided by this Guide. Larger systems may already have at hand all of the information contained herein. Some of the material in this manual is pertinent to all water systems. Site specific analyses by competent consultants will generally provide expertise greater than this manual, and such assistance is often necessary if new programs of investment are suggested.

Each Section of the Guide begins by asking a series of common questions concerning the topic of the Section. Following each question there is a reference to material in the Guide which will aid in answering the question. The text provides a general overview of many pertinent aspects of potable water supply.

Each major section is prefaced by a graph which outlines Section content and gives respective page numbers. A list of outside references is provided at the end of each section to assist in finding further details of each topic discussed. For problems not solved by the reference material, specialists in administrative, legal, or technical aspects of water supply should be consulted in their areas of expertise.

PART 1

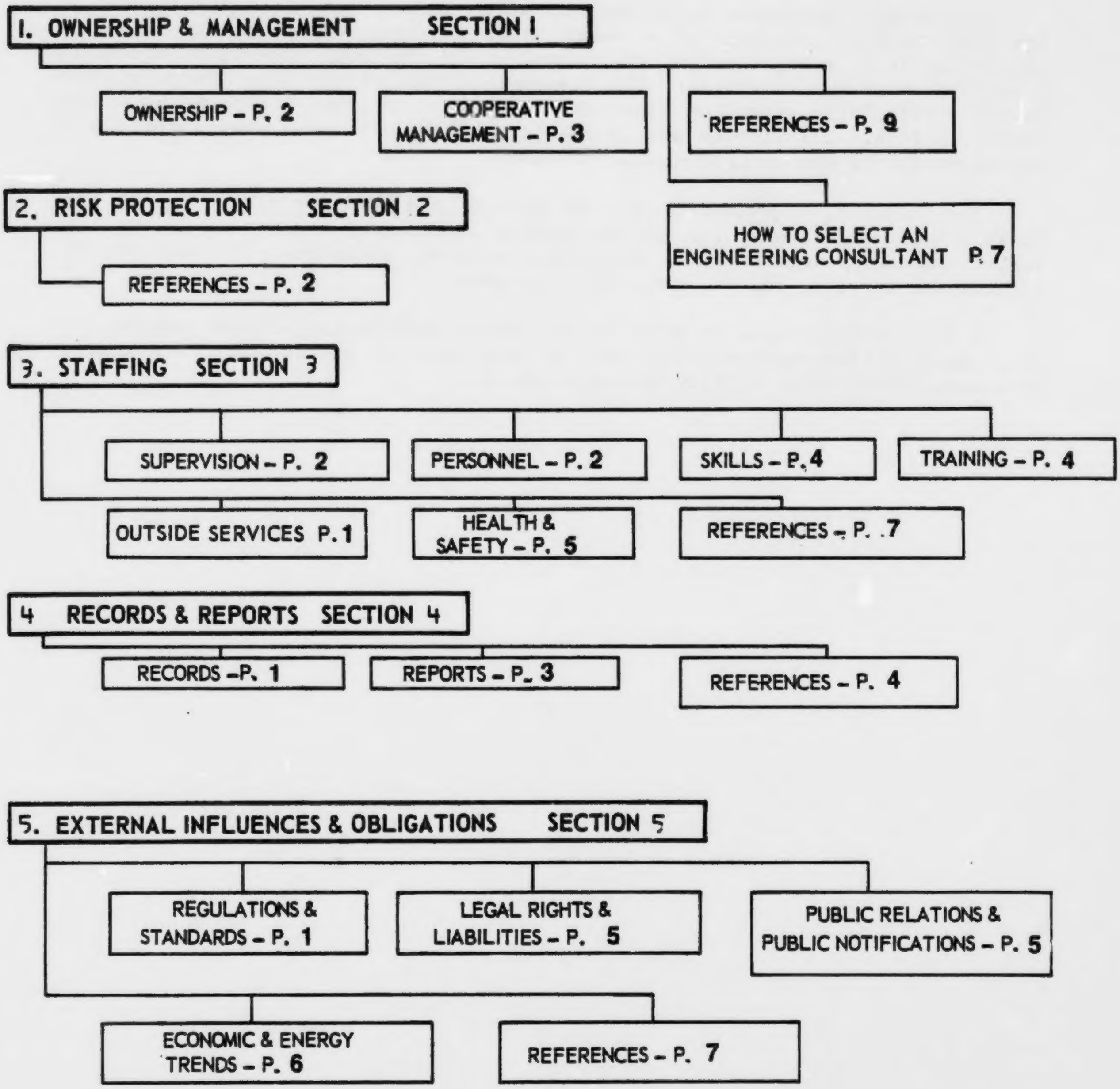
INSTITUTIONAL

The primary decisions to be made by water utility officials are related to the institutional concerns of a water supply system. These include such key factors as utility organization and ownership and the legal aspects of operating a potable water supply system. The responsibilities of the water purveyor have become particularly demanding since the passage of the Safe Drinking Water Act (SDWA) in 1974. Liabilities are increasing, as are the requirements for public participation in the decision-making process.

The information presented in this part of the decision-maker's guide provides a brief overview of the various aspects of managing a water supply utility. Topics including organization, personnel, external influences and obligations, records and reports, and insurance are discussed.

A list of references is given at the end of each section. These sources contain detailed information which may be necessary to answer specific, complex questions facing water utility decision-makers.

PART I
INSTITUTIONAL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SECTION 1

OWNERSHIP & MANAGEMENT

QUESTIONS ABOUT ORGANIZATION OF WATER SYSTEMS

There are several questions which those responsible for public water systems should ask with regard to the organization of their enterprises. These questions relate to the ownership, administration, and management aspects of the operations. The questions may be different depending on whether a new water system is being contemplated, or whether changes are being considered in the operation of an existing system. Included in these two categories of questions concerning organization are the following:

Existing Systems

1. Should the ownership as it now exists be continued, or should a sale or transfer to new ownership be considered? (See pages 1- and 1-3)
2. Should the water utilities in the vicinity be combined to operate under a water authority or a regional government? (See page 1-5)
3. What area should the utility attempt to serve? (See page 1-6)
4. Is it better for the water system to operate as one of the departments of a government entity or as an independent agency with its own board of directors? (See page 1-2)
5. Can the water system manager discharge his duties to the State under the Safe Drinking Water Act on his own, or should he seek legal, engineering, or financial advice from consultants? (See page 1-7)
6. Is some reorganization needed? (See pages 3 to 7 and 5)
7. How should an engineering consultant be selected? (See page 1-7)
8. What contacts are needed with other agencies? (See Section 5 , page 5-2)
9. Should cooperative arrangements or joint-power agreements be sought with other agencies? Can cooperation with others be advantageous in billing customers, operation of laboratories, providing technical assistance in water plant operations, or other areas of common need? (See page 1-3)

New Systems

Some questions posed under Existing Systems also may apply to new systems.

10. What enabling legislation is there and what are the legal constraints? (See Section 5)

11. Should the water system be organized under public or private ownership? (See page 1-2 and 1-3)

12. Will fire protection be provided under private ownership? (See pages 1-2 to 1-4)

13. Should annexation to an existing nearby water system be sought? (See page 1-5)

14. If water system is owned by a city, should there be a separate water board, or should a water department be formed under the existing city administration? What are the interdepartmental relationships? (See pages 1-2 and 1-3)

Information concerning some of these questions will be given in this section of this report. Other questions will be answered in subsequent sections.

OWNERSHIP

Water systems may be either publicly or privately owned. Rural water systems which are cooperatively owned by the individuals served are considered publicly owned in this report. Privately owned water systems are operated as a business, including methods of day-to-day operation and in relationships with employees.

Except for entirely new systems, the decision on private versus public ownership was made long ago. Any decision made now to change ownership is likely to stem from financial or political considerations. One common reason for considering a possible change in ownership is that the owner cannot afford the necessary improvements to the water system. The motivation for a change may originate with the owner who wants to be free of a financial burden, or from water users who are dissatisfied with water quality or water service and want to improve the system.

The majority of water supply systems in the United States are publicly owned entities; however, for each community the decision regarding public versus private ownership should be based on the ability to supply the best service at least consumer cost under local conditions. Service should be provided in an environmentally sensitive manner consistent with land use and water conservation and development plans.

Alternatives

Ownership and control of a public water utility can be as a private or governmental enterprise.

- Private Ownership - A privately owned water utility may be organized as a corporation, partnership, or a single owner. Ownership is generally vested in a group of stockholders who control operation through a board of directors and, ultimately, a chief executive or president. Day-to-day operation can be managed by a full time or a part time operator or under a lease-service arrangement. The manager would report to the Owner or Board of Directors.

- Public Ownership - The community property owners or taxpaying public usually represent the controlling body for a publicly owned utility. In this case, control is directed through elected officials, who may in turn, appoint the manager of the facility. Organization of a publicly owned facility varies considerably among agencies, depending on specific needs and enabling legislation. The water department may be incorporated into other city or municipal departments, or be organized as a separate institutional unit, such as a district, board, or authority, which is relatively autonomous with respect to other municipal management functions. In addition, it may be part of a regional authority.

Considerations

The prime considerations concerning utility ownership are institutional, management efficiency, the ability to provide needed services, and profit. Overall, privately owned systems have an excellent track record, and, in certain cases, a privately owned organization represents a more efficient alternative to public ownership.

Public ownership is not always feasible but is generally preferred when a private investor cannot operate effectively under the associated constraints of low profit margins and large capital investments. Furthermore, many operations are often best organized as a subdivision of, or jointly with, other municipal services and governments. In small cities many operating responsibilities, such as accounting, billing, reporting, etc., can be combined with other municipal services. Public responsiveness of publicly-owned water utilities may be better than that of private water companies. Also public water systems may be eligible for some state and federal assistance which is not available to private companies.

The trade-offs between private and public ownership are summarized in Table 1-1.

COOPERATIVE MANAGEMENT

There are several forms of cooperative management which may be applied to water works administration. There can be internal cooperation within a single community or formal or informal cooperation among several communities.

1. Single Community - In instances where the water system is operated as one department of several within a single city or community, there are several opportunities for potential efficiency and savings through interdepartmental cooperation and sharing of personnel and facilities. There may be combined administration of water and wastewater facilities or of all public works facilities in the city. Or there may be a sharing of computer facilities, communications equipment, automobiles, construction and maintenance equipment, or billing and accounting staff. Certain insurance policies may cover several city departments. These internal arrangements may be advantageous or not, depending upon local circumstances. In many communities, a single-purpose, separate and

TABLE 1 -1. ADVANTAGES AND DISADVANTAGES OF PUBLIC AND PRIVATE OWNERSHIP

Alternative	Advantages	Disadvantages
Private Ownership	Profit motive Autonomous from municipal government Not affected by debt limitations of municipal government	Taxable Cannot raise revenue through taxation Low profit margin complicates investment and management Failure by utility regulatory agencies to allow recovery of fire protection costs in rate structures may limit ability to provide fire protection
Public Ownership	Generally lower rates due to exemptions Higher exposure to public Can sell tax exempt bonds at low interest rates and obtain government grants Can obtain income through taxation Can better utilize income from customer contributions	Politicial constraints

independent water board, commission, or department may be the best form for management and administration, particularly where there is not sufficient attention or emphasis on water programs, or where there has been harmful political interference with water system operations or finance.

2. Regionalization - In some situations where several cities or community systems are located in proximity and are providing similar services, there have been efforts to create a single new political or institutional entity to replace the several separately managed ones. In the implementation of the Safe Drinking Water Act (SDWA) both Congress and the Environmental Protection Agency (EPA) recognized the potential utility of regionalization in solving some of the practical problems facing small systems. For instance, Section 1416 of the SDWA provides an additional two-year period for systems entering into a regionalization program. The extra time period allows for the negotiation of institutional and administrative details.

EPA encourages the consideration of regional systems as a means of resolving some very difficult problems. Economies of scale, capital resource pooling, and improvement in operation are some of the advantages of regionalization.

The pooling of skills, resources, and knowledge has long been recognized as an appropriate method for enhancing a program. Regionalization, as applied to public water systems, can be defined as an interconnection of existing systems or the centralization of one or more management functions for several water systems that are not physically interconnected.

The benefits of regionalization go beyond that of providing a means by which a public water system can meet the requirements of the SDWA. Four major areas that may benefit through regionalization are operation and maintenance, financing, planning and design, and relations with regulatory agencies.

The pooling of financial resources can allow for the hiring of a few qualified personnel to properly manage, maintain, and operate a group of consolidated public water systems instead of the part-time operators who are all too frequently underqualified and undertrained. The unified management of a regional system may improve service and water quality through comprehensive and knowledgeable supervision and direction of operations. Also, a water system with a sound personnel base is better able to attract, retain, and train qualified personnel. Other operation and maintenance benefits include better reaction to emergency situations, sharing of physical facilities, and standardization of construction materials.

For small public water utilities which are fiscally handicapped by their size, the difficulty in raising money to update their systems to improve service and water quality and to meet the SDWA requirements may result in a financial burden for the users. Through regionalization, capital costs can be distributed over a larger user base. The larger base also may make it easier to raise funds for public water system improvements. The opportunities to finance necessary projects solely on a service charge basis may be enhanced by providing a larger base for revenue, which will encourage better bond ratings. In addition, a more uniform rate structure is possible.

A central public water system or regional management of a group of small, scattered systems may provide better water resource management to meet the water supply needs within a given area by increasing planning options. Because of the larger geographical area of operation, the regional system may more easily take advantage of multiple sources of water supply, thus utilizing the best available raw water supply within a given area. This in turn provides greater latitude in the choice of treatment and thus greater control over capital costs. Many drought-related problems of individual systems might be relieved if systems become a part of a regional system.

The continued proliferation of small water systems creates problems. Additional water systems mean a dilution of existing monitoring and technical assistance capabilities. Moreover, small systems are more likely to require outside assistance in solving operation and maintenance problems.

A significant proportion of small water systems in the US might benefit through regionalization. Unified purchasing, operation, maintenance, monitoring, planning, and financial and administrative management functions could be carried out by a single staff. This consolidation might lend a stability and economic base to these systems which they do not currently possess. Further, the administration of all of the functions by a regional entity may allow the consolidated system to enjoy the economics of scale and the resultant savings.

Despite its advantages, regionalization is not considered a panacea. In some places, the replacement of several governmental units by a new regional agency has been accomplished successfully. However, in many instances this approach has met with great resistance and opposition. The objections to regionalization of governments, where it exists, stem from several sources. There is community pride and inter-community rivalry. There is resistance to change in established political institutions, and there may be legal and financial difficulties in regionalization. Communities considering this approach should study the experience gained in previous attempts by others in this direction before initiating a local program, in order to anticipate problems and develop local support.

3. Multi-Community Cooperative Administration - For groups of neighboring communities desiring to obtain some of the advantages of consolidation without the political and administrative difficulties of regionalization, multi-community cooperative administration may offer an

alternative. It might be advantageous for several communities to share a manager, an accountant, an engineer, or a chief water works operator. They may share the use of laboratories, of facilities for sample collection, or of construction or maintenance equipment, or they may stock a common supply of repair parts or emergency equipment. To date, this type of cooperative management has not been widely used, but offers definite advantages. Under the SDWA, the new water quality considerations make the operation and management of water systems somewhat more technical than in the past, which poses problems for many communities, particularly small ones. The required managerial, engineering, and technical skills for water systems may be more readily obtained in some cases through multi-community cooperation.

Clearly, the alternatives for water supply operation and organization are many. Each community or utility must evaluate the alternatives relative to its own specific needs and situation. Some of the main considerations of utility organization are summarized in Table 1-2.

HOW TO SELECT AN ENGINEERING CONSULTANT

Except for very large cities, most water managers or directors find it necessary to employ consulting engineers to design water works improvements or new water facilities, because of the specialized nature of the work to be done. It may be particularly important to hire a consultant to design improvements needed to bring a system into compliance with the National Interim Primary Drinking Water Regulations (NIPDWR). Some questions to be asked in this regard include:

1. Is the engineer licensed or registered to practice Civil or Sanitary Engineering in the State?

2. Is the engineer qualified and experienced in the type of work to be done?

3. Have the results of his work for other clients on similar projects been satisfactory? Have his references been checked, particularly with persons who have been responsible for operation of facilities designed by the engineer?

4. Will the engineers who actually do the work within the firm be persons with the necessary experience?

5. Is the engineer familiar with the State regulations?

Further information on selecting a professional engineer is contained in two publications, as follows:

1. American Society of Civil Engineers, Manual 45, "Consulting Engineering, A Guide For The Engagement of Engineering Services," available from the ASCE, 345 East 47th Street, New York, NY 10017.

TABLE 1-2. SUMMARY OF THE ADVANTAGES AND DISADVANTAGES OF WATER UTILITY MANAGEMENT ALTERNATIVES

Alternative	Advantages	Disadvantages	Favorable conditions
Single Community			
Directly under general community administration	Opportunities for interdepartmental cooperation	Cost may be high in small communities	Large and small communities
	Direct accountability	Less time to spend on water problems	
Under separate water board	Autonomy & simplicity of administration	Cost may be high in small communities	Large communities
	More attention of top officials to water problems	Less opportunity for interdepartmental cooperation	
	Direct accountability to public		
Regionalized Government & Water Authorities	In some cases overall economies of scale can maintain more competent technical & maintenance staff	More complex administration	When optimum water service area boundaries do not coincide with existing political boundaries
		Requires cooperation between political units	
	Low interest financing may be more available	Less accessability to public	Existence of several closely-grouped communities
Multi-community cooperative administration	Overall economies of scale	Less accessibility to public	When joint cooperative effort by neighboring communities can improve operation of water systems that they cannot accomplish individually
	Can maintain more competent staff; technical, operational, and maintenance		
	Flexibility		Small communities
	Adaptability to emergency conditions		

2. National Society of Professional Engineers, Guide For "Selecting, Retaining, and Compensating Professional Engineers In Private Practice," available from the NSPE, 2029 "K" Street N.W., Washington, DC 20006.

Water works engineering is a highly specialized profession. It is important for water system managers and officials to obtain the services of a firm which has thoroughly trained personnel who are well experienced in water system planning, design, construction and operation. The selection of the right consulting engineer is highly important to the successful completion of water system improvement programs.

REFERENCES

- "Water Utility Management," American Water Works Association (AWWA) Manual M5. Chapter 1 deals with questions of ownership and regulation of water supply utilities.
- Urban Public Works Administration, W.E. Korbitz, ed., International City Management Association, 1976. Chapter 2 deals with the organization and interrelationship of various public works organizations.

SECTION 2

RISK PROTECTION

RISKS & INSURANCE

Water system managers have several decisions to make regarding the risks involved in water system ownership and operation, and how to protect the owner against excessive losses.

1. The basic questions are how many risks can be assumed presently by the utility (self insurance), and how many risks should be covered by insurance? (See pages 2-1 and 2-2)
2. What types of insurance are available? (See this page below)
3. What public liability risks are incurred by water utilities? (See page 2-2)
4. How often should insurance programs be reviewed? (See page 2-2)

Types of Risk

Water systems may be exposed to losses from: windstorm, fire, flood, theft, libel, slander, violation of privacy, damage to boilers and machinery, lightning, water damage, collapse, loss of records and drawings, injury to employees, auto collision, public liability, crimes by employees, burglary, robbery, forgery, earthquake, and product quality.

Coverage

Comprehensive coverage is not a type of insurance carried by a water system. Most comprehensive contracts require the disclosure to the insurance company of all hazards. Many of these may not be known to the owner. Thus, there are likely to be gaps in the coverage provided.

Property Loss or Damage

A property loss or damage policy for water systems should cover the replacement of facilities or equipment at the market value at the time of loss. Individual components of the water system should be assessed for vulnerability to specific types of damage. Vandalism of water systems is common and consideration should be given to insurance to cover such losses.

Workmen's Compensation

This insurance is generally required by law. Such policies must comply with individual state laws as to the amount, type, conditions, and extent of coverage. The coverage may be a substantial budget item and should not be overlooked as an employee benefit. Often, the policy cost is based on the claim history; enforcement of safety rules can be a decisive factor in reducing this cost.

Public Liability

Liability insurance covers both personal and property damage. Hazards such as false arrest, libel, slander, etc., as well as death and disability, are included. The increased responsibility for meeting SDWA requirements may necessitate consideration of product insurance coverage. One difficulty in writing liability policies is defining the conditions to be covered and determining the extent of coverage.

Product Insurance

Protection against possible claims of polluted or unsafe water may be provided by carrying product insurance. Under the SDWA, class action suits are prohibited. A citizen may sue if a water system is out of compliance. However, if the water utility has an exemption or variance, it is protected against citizen suits.

Crime Coverage

Crime coverage can be broken down into two general categories - employee and outside. The most effective way of providing crime insurance is to have the employee "honesty bond" included with the "money and securities" policy which would cover burglary, robbery, vandalism, etc.

Self Insurance

Because of the high cost of coverage or lack of availability, water utilities often do not carry flood or earthquake insurance. Also, as previously mentioned, deductible limits may be set with regard to prudent self insurance capacity so as to reduce insurance costs.

Securing insurance coverage should be approached cautiously. The fact that insurance policies are contracts should not be overlooked. They must be reviewed critically and revised to the satisfaction of the water utility.

The number of policies to be carried by a water utility varies according to load conditions. Grouping of coverages under fewer contracts may be advantageous under many conditions. The selection of the insurance carrier may be by negotiation or by competitive bidding. Again local circumstances may dictate this choice. The whole insurance program should be reviewed annually to take into account acquisitions and dispositions, value changes, and other changes.

REFERENCE

- "Water Utility Management," AWWA Manual 45, Chapter 17. Discussion of the various types of insurance that should be carried by a water utility, including comprehensive coverage, property loss or damage, workman's compensation, public liability, crime coverage, etc.

SECTION 3

STAFFING

Proper selection, organization, and management of the people who are employed to operate the water department greatly influence the success of the water system in providing proper service to its customers. With small and medium sized systems one of the basic decisions to be made is how much of the work is to be done in-house by permanent or temporary staff, and how much can be done better or more efficiently by outside contract.

Some pertinent questions are:

1. How much help is available? (See this page, below)
2. What number and mix of personnel is needed to staff the water department? (See pages 3-2 to 3-5)
3. What services can be contracted to advantage? (See pages 3-2 and 3-3)
4. How can the technical and managerial expertise of the water department be increased at low cost? (See pages 3-4 and 3-5 and Table 3-1)
5. What factors influence staffing requirements? (See pages 3-2 and 3-5)
6. What kind of health and safety program is required? (See page 3-5)

OUTSIDE SERVICES

Because water utilities are subject to regulation by local health departments, state agencies, and the federal government, some technical assistance is available at no extra cost from these regulatory agencies. City or County health departments can furnish information regarding regulations which must be met by public water systems. They also can provide instruction in the collection and submission of water samples for bacteriological, chemical, or radiological analysis. Some or all water system samples may be analyzed in local health department laboratories. They can assist in the interpretation of the reports of test results. State water agencies can also provide these services. In addition, states can provide technical assistance with treatment plant operations, operator training, the selection of a consulting engineer, and with application for grants and loans. In states which have not assumed primacy (primary enforcement responsibility) under the Safe Drinking Water Act (SDWA), the Environmental Protection Agency (EPA) can provide these services.

Because the design of water purification plants is such a highly specialized undertaking, most water systems, even large ones, usually engage a consulting firm experienced in water treatment plan design to prepare plans and specifications for new or expanded plant work. Consulting engineers also can assist in operator training, plant startup, or in plant operation. They may prepare plant operations manuals to aid plant operators.

Regulatory agency representatives and consulting engineers also are available to assist water systems in times of emergency.

Some equipment manufacturers or suppliers provide maintenance services under water department contract, particularly for control systems and monitoring equipment.

Legal and financial advice can be obtained from local attorneys, lawyers specializing in water rights, or from financial institutions such as bond houses or banks.

Help also may be obtained from other water system operators in the area or the local section of AWWA.

SUPERVISION

The key to the manner in which a water system is operated is the manager. He must be given and he must assume the primary responsibility for the proper operation of all facilities. The first responsibility of the manager is to provide safe water. His other direct responsibilities may vary quite widely depending on the size and complexity of the particular water system he is managing. In some cases, the water system may be operated by one person, who must do everything necessary. For all other systems, a clearly defined organization should be established.

A basic chart showing the various positions and supervisory levels should be available to all personnel. The relationships among groups with different functions should be well defined. A chart with names should be given to each individual within a work group.

As in any business, it is important that the established organizational structure is followed. Communication must be through the proper channels, with directions coming through each employee's immediate supervisor.

As a general rule, the number of people supervised by anyone should be limited to six. This ensures adequate opportunity to establish good communication while reducing the chance of having a "top-heavy" organization with too many managers.

An individual should have only one supervisor.

PERSONNEL

Staffing requirements depend on numerous factors, including:

- The extent to which outside services are utilized
- The size, complexity, and age of the water system
- The source of supply and water treatment requirements
- The degree of instrumentation and automatic controls

- The relationship to other utility services

- The degree of individual staff utilization and overall organizational efficiency

- The extent of operational attendance required

In assessing staffing requirements, the best sources of information are the historical records for the facilities. If the records are poor or staffing is being estimated for completely new facilities, operational information from similar facilities may prove useful. The water system should be divided into functional groups, such as supply, treatment, distribution, and administration, which may be further subdivided. Treatment, for example, could be broken down into process operation, maintenance, buildings and grounds, and laboratory. The sum of the estimated annual manpower needs for each task and level of responsibility will give the overall staffing requirement.

Unionization is an important consideration which can have both advantages and disadvantages.

In any event, formal arrangements should be made for good communications between the manager and all employees. There should be freedom to discuss wages, working conditions, and fringe benefits. A procedure should be set for filing grievances.

Job opportunities should be made known to all employees and all employees should be given full consideration in employment.

Recommendations for optimum surface water treatment plant and distribution system staffing are as follows:

SURFACE WATER TREATMENT PLANT STAFFING

	Plant Capacity, mgd		
Position	1	10	50
Plant superintendent	1	1	1
Assistant plant superintendent	0	0	1
Chemists and bacteriologists	0	1	3
Chemical building operators	0	1	4
High and low service pump station operators	0	2	8
Filter plant operators	4	4	4
Maintenance mechanics	0	1	5
Utility helpers	1	4	12
Storekeeper	0	1	1
Stenographer	0	1	1
TOTALS	6	16	40
DISTRIBUTION SYSTEM			
Operation and Maintenance, Total	3	5	15

For small systems, individuals will be responsible for many different tasks, while for larger systems, more than one individual may have the same general duties for multiple shift operation. In all cases, the level of responsibility should be defined in a written job description including:

- Work group
- Position of immediate supervisor
- Job description - duties, responsibilities, limitations
- Job title
- Qualifications - skills, education, and experience requirements

Appendix B of the EPA "Technical Guidelines for Public Water Supplies" contains typical job descriptions for twenty-one positions (see reference at the end of this section).

All new employees should be carefully interviewed and fully informed of the conditions of their employment. These include such matters as:

- Economic incentives including employer-paid benefits
- Organizational structure
- Duties and responsibilities
- Possible risks associated with the job
- Expected performance standards
- On-the-job training
- Scheduled performance and salary reviews

Emergency Staffing

Contingency plans should be made to operate the water system in the absence of regular personnel due to illness, strike, or other emergency.

SKILLS

Employee skills should match operational requirements as determined from the detailed job descriptions. Operator certification is another method of matching skills and job assignments. In some states it is mandatory, while in others it is optional. In either case, it provides a standardized classification system by which individuals may be placed in positions.

TRAINING

Training is perhaps the lowest cost method available for increasing the technical and managerial expertise of the water department. All employees should be encouraged to participate in training programs and refresher courses. They can perform best if they are informed of current practices related to their jobs. They should be encouraged to maintain or improve their current skills as well as acquire new skills to prepare for possible advancement.

There are various training aids, including:

- Formal orientation of new employees
- Consultant's presentation of O&M manuals

- Manufacturers' operation and maintenance instructions on new equipment
- Individual on-the-job training by supervisor
- Instruction by state agency, local health dept., EPA, or consultant
- Group or classroom on-the-job training
- Short schools sponsored by professional organizations, state agencies, or vocational schools
- Correspondence courses
- Extension, part-time, and full-time courses taught by instructors from local vocational schools, colleges, and universities

Advantages and disadvantages of three general approaches to personnel training are summarized in Table 3-1.

HEALTH AND SAFETY PROGRAMS

A comprehensive safety program is an essential tool in preventing accidents and protecting employees. The safety program should be established and fully supported by top management. Supervisors must inform all staff members of the safety program and see that it is carried out.

Basic considerations to promote plant safety include:

- Comprehensive "hands-on" training and classroom instruction regarding safety equipment operation, maintenance, and repair

- Basic protection against potential dangers at facilities (i.e., machinery guards, handrails, hazard warning signs, adequate lighting, suitable tools, etc.)

- Regularly scheduled safety meetings

- Good housekeeping (i.e., removal of debris and flammable materials)

- First-aid training

- Regular inspections, both scheduled and unscheduled, by the safety committee

State and Federal Occupational Health and Safety Act (OSHA) standards must be followed.

Safety records and accident reports are the best means of assessing the effectiveness of a safety program. As well as comparing the current safety record with previous year's records for the system, it should be compared to published safety reports or records for other utilities. An example of this is the annual water utility disabling injury rates published by the Accident Prevention Committee of American Water Works Association (AWWA). Additional statistics on safety and accidents may be obtained from the National Safety Council.

TABLE 3 -1. ALTERNATIVE METHODS OF PERSONNEL TRAINING

Training method	Advantages	Disadvantages	This training can be obtained from
On-the-job training	Learning is in a practical situation, trainee can see and hear the operation	Generally one-way communication, difficult to set up, may place heavy demands on instructor, limited number of trainees can participate	Job Supervisor Equipment suppliers Consulting engineers State personnel Personnel from other utilities Local Health Dept.
Correspondence course or other educational packages	Cost/man hour is usually low, trainees are actively involved, instruction is self-paced and consistent. Materials have been pretested and their effectiveness has been proven	Slow feedback, no instructor for supplemental guidance, requires high level of motivation, and can be difficult to teach "hands on" experience because specific self-instructional materials are not always readily available	Private correspondence schools (ICS) Universities and junior colleges Vocational schools Professional organizations Some State agencies Textbooks
Classroom instruction	Less time-consuming, much material can be covered quickly, fewer interruptions allow instructor to pursue objectives, and the same lecture can be given to more than one group with little in-between preparation	Communication is one-way, opportunities for misunderstanding of information are great, lectures cannot be tailored to individual needs, and lack personal trainee involvement. Planning a lecture that will hold the interest of the trainees is difficult	In-house by supervisors State and Federal agencies Universities and junior colleges Consulting engineers Equipment suppliers Local Health Dept. Personnel from other utilities

REFERENCES

- "Technical Guidelines for Public Water Systems," U.S. EPA, June, 1975, NTIS #PB 255 217. Chapter 10 given information on staff requirements and organization, training and education programs, certification, etc.; it also discusses safety programs. Appendix B has descriptions for twenty-one typical water utility jobs.

- "Safety Practices for Water Utilities," AWWA Manual M3. Discusses need for safety program, starting and maintaining such a program, and specific safe work practices (operating tools, handling chemicals, etc.).

- "Water Utility Management," AWWA Manual M5, 1959. Chapter 2 discusses organizational and management practices; Chapter 18, personnel management; Chapter 19, training programs; and Chapter 20, safety programs.

SECTION 4

RECORDS AND REPORTS

Managerial decisions regarding the maintenance of records and preparation of reports influence operating costs for water systems because they are time consuming activities. Therefore, it is important to answer the following questions:

1. What purposes do records and reports serve? (See this page, below)
2. What records should be kept and what records should be discarded? (See pages 4-3 and 4-4)
3. How long should records be maintained? (See page 4-2, Table 4-1)
4. What are the best ways to preserve records? (See page 4-3)

RECORDS

Record keeping and reports are essential elements of a well run water system. Records serve as historical and legal documentation for the system, and reports are the means by which this information is distributed. The two go hand-in-hand with analysis and interpretation, which are important aids to successful operations.

Records of data collected fall into several categories. These are:

- Service - customer connection files, billings, accounting, complaints, etc.
- Construction and Maintenance - dates and details of plant improvements and repairs, valve operation and distribution system flushing schedules
- Operations - system O&M, equipment and supply inventories, surveillance, etc.
- Quality Control - records of performance
- Personnel - employee records (evaluations, staffing, statistics, staff planning, etc.)
- General Management - policies, planning, finance, organizational structure, etc.

The adequacy of record keeping can be judged by the usefulness of the information collected. Records should be clear and concise; they should contain all essential information without having superfluous or incomplete data in them. They may be used to project future conditions, plan system and service changes and improvements, and increase overall operational efficiency.

Methods of record keeping vary, depending on the size of the system, the services offered, and the relationships with other utilities. For small systems, manual record keeping may be adequate. For larger systems machine processing of data may be advantageous. If water is provided along with other services, records should reflect the interrelationships and the effectiveness of combined operations for some functions. Consistency of record keeping by different recorders, especially those on different shifts is important.

Records of Operation & Maintenance

Record keeping is an essential function of plant operations and maintenance. A brief review of the system records will show the effectiveness and efficiency of operations. A detailed review of records may point to obvious areas where improvements are needed. Well designed summary reports will best allow for good week by week administration.

Records are important for several reasons:

- They demonstrate compliance with regulations and standards.
- They provide historical information on the system which will aid in planning future expansions and modifications.
- They reflect the adequacy of current operations.
- They are necessary for the preparation of annual reports.
- Records of valve operation are needed to insure that seldom used valves will function when required.
- They assist in routine administration such as chemical purchases and budgeting.

Preservation of Records

The length of time records should be kept depends on the water system and the type of records. Table 4 -1 summarizes the length of time some of the more important operations records should be kept to satisfy the requirements of the SDWA.

In addition to the records required by the State, it is a good idea to keep records of power and chemical purchases, personnel, budget, water sales, and other items.

Reports of engineering surveys and studies are often kept for more than 10 years, since they may contain data which will be useful in subsequent surveys. Much valuable information is lost due to indiscriminant disposal of records.

TABLE 4 -1. MINIMUM RECOMMENDED DURATION FOR RECORD KEEPING BY SDWA*

Records	Duration
Bacteriological analyses**	5 years
Chemical analyses**	10 years
Written reports such as surveys, engineering reports, etc.	10 years following completion
Variances or exemptions	5 years following expiration
Action taken to correct violation	3 years after last action taken

* There also may be additional State requirements.
** Mandatory records.

In time the bulk of records accumulated may make it advisable to microfilm some records. It may be desirable to store records in a safe or a vault for protection from fire and flood.

REPORTS

Good records are not useful unless they are properly analyzed, with the findings clearly reported. Reports may be in a number of forms, depending on the purpose of the report and the size of the system. Examples of the various types of reports are:

- Monitoring Reports - monthly reporting to the state of routine sampling, check sampling of violations, and violations (these must be reported within 48 hours of a confirmed violation). Public notification of violations is discussed in Section 3 .

- Annual Reports - Annual reports serve to keep the customers and stockholders informed of the past activities and future plans. To be an effective public relations instrument, such reports should be interesting, concise, and attract the audience's attention. They should summarize system statistics, preferably illustrated with simple graphics or photographs; discuss any major events or changes which occurred in the past year; and have a financial statement for the last three to five years. Since the audience is a specific, non-technical group, professional help in preparing this report may be useful. Common ways to distribute annual reports are through the newspaper as an article or supplement, or by mail as a bill enclosure or in a separate mailing. A comprehensive annual report should be available to individuals who wish more information regarding system operations.

- Special Reports - Special reports aimed at a specific audience or for special communications such as water conservation programs or system expansions may be needed. These should be non-technical in nature and can take the form of newsletters or bill enclosures.

- Management Reports - Management reports may take many forms and are generally intended for internal use. They are tools by which the managerial staff can assess the system and plan future improvements. They may cover such topics as finance and budget, staffing, production, efficiency, maintenance, quality control, and expansions. Depending on complexity, extent, and type of report, they may be prepared in-house or by an outside consultant.

- Construction Reports - Progress, etc.

Evaluating the adequacy of reports is important to insure that they are serving the purpose for which they are prepared. Reports must be functional. Unnecessary report writing is a costly undertaking, while insufficient reporting can reduce the efficiency of the operation and effectiveness of good record keeping.

The best way to evaluate the adequacy of a report is to ask a few simple questions.

- Is the original intent or goal of the report satisfied? Is the intended audience being reached?

- What information is being conveyed? Can it be easily understood by the audience?

- Is the report a useful tool? If not, should the report be dropped or restructured?

REFERENCES

- "Water Utility Management," AWWA Manual M5. Chapter 12 deals with accounting records and procedures; Chapter 18, with personnel records; and Chapter 22, with annual reports.

- "The Safe Drinking Water Act; Self-Study Handbook; Community Water Systems," AWWA, 1978. Chapter 5 outlines basic record keeping procedures and has example forms; Chapter 6 discusses the reporting procedures required by the SDWA.

- Urban Public Works Administration, W.E. Korbitz, ed., International City Management Association, 1976. Chapter 3 includes the use of computers for record keeping, information systems, and performance evaluations.

SECTION 5

EXTERNAL INFLUENCES AND OBLIGATIONS

Supplying of water to the public for domestic, commerical, and industrial purposes is itself a commercial undertaking involving financial and professional responsibility. The quantity and quality of water supplied affects the health and economic well being of everyone in the community. For these and other reasons, local, state, and Federal laws and regulations have been developed which seek to protect water users against inadequate or hazardous water supplies.

Water supply is a public trust. Water purveyors have many legal obligations, and they must be responsive to many external influences.

The need to produce a sufficient, safe supply of water at a reasonable cost presents water managers with many questions to be answered if proper decisions are to be reached. Some common questions include:

1. What are the regulations? (See Appendix A-Also see State regulations)
2. What are the reasons for the regulations? (See Appendix B)
3. What are some of the options for meeting the regulations? (See pages 5-4, 5-5 and Section 8)
4. What are the potential health risks in drinking water? (See Appendix B)
5. What are the trade-offs between cost and water quality? (See page 5-4)
6. Where can detailed information be obtained on methods for treating water in order to meet State standards and the National Interim Primary Drinking Water Regulations (NIPDWR)? (See page 5-3 and Section 8)
7. What are some ways to involve the public in the decision making process, particularly in the light of public notification requirements? (See pages 5-5 and 5-6)
8. Water rights. (See page 5-5)
9. What are the effects of current economic trends and energy considerations on water works operations? (See page 5-6)
10. What are the options available for the delivery of sufficient amounts of water to meet emergency situations? (See page 6-8)

REGULATIONS AND STANDARDS

There are state and federal regulations which affect all community and non-community public water supplies. In some locations there may also be applicable city or county health department regulations. Under the 1974 Safe Drinking Water Act (SDWA) most states have assumed the primary responsibility (primacy) for enforcing the NIPDWR. In a few states, the Federal Environmental Protection Agency (EPA), has this responsibility. Local and state jurisdictions may have requirements in addition to those of EPA.

By Congressional passage of the 1974 SDWA, the EPA was delegated the responsibility of developing water supply standards and an associated implementation plan for the protection of public health. In response, the EPA promulgated the NIPDWR, which became effective on June 24, 1977. These regulations, which are currently in effect, establish maximum contaminant levels (MCL's) and monitoring requirements for selected organic, inorganic, and microbiological contaminants. The NIPDWR which were published in their entirety in the Federal Register, December 24, 1975, are summarized in Appendix A. They are applicable to all public water supplies; however, may be superseded by more stringent state or local requirements. Enforcement of the NIPDWR currently may be either or both a state or an EPA responsibility, depending on location.

The SDWA also established a mechanism whereby the NIPDWR may be revised based upon recommendations of the National Academy of Sciences (NAS) or based on other data. The objective is to amend the interim regulations such that the resulting NIPDWR represent the state-of-the-art regarding health and technical feasibility of potable water supply. The revisions to the NIPDWR recommended by NAS are summarized in Appendix B. The amended standards are expected to be issued sometime in 1980. Changes or amendments to the regulations can be made by the states or EPA when merited.

An important aspect of the SDWA is the Public Notification Requirements which were included in the Act to ensure that consumers are properly informed of NIPDWR violations and the associated potential health hazards. Public notification requirements address specific types of violations and are different for community and non-community public water supplies.

A community system has at least 15 service connections used by year-round residents or serves at least 25 year-round residents. These water systems generally serve large apartments, institutions, communities, condominiums and mobile home parks.

A non-community system has at least 15 service connections used by travelers or transients at least 60 days a year or serves 25 or more people daily for at least 60 days a year. Examples include separate water systems which serve motels, restaurants, campgrounds, churches, factories, lodges, medical facilities, rest stops along interstate highways, roadside service stations, and day schools. Please note that if the establishments mentioned above are served by a community water system they are considered to be a part of that system and therefore are not subject to separate regulations.

Requirements for community systems are summarized in Table 5-1. Non-community water supplies are required to report non-compliance of NIPDWR in a manner that will ensure the user is adequately informed of the violation and potential risks. This distinction was necessary because non-community systems typically

TABLE 5-1. PUBLIC NOTIFICATION REQUIREMENTS FOR COMMUNITY PUBLIC WATER SUPPLIES

Type of non-compliance with NIPDWR	Required notification Mail	 Newspaper	 Broadcast
Violation of MCL	x	x	x
Failure to monitor	x		
Failure to follow compliance schedule	x		
Failure to use approved testing procedure	x		
Having variance or exemption	x		

serve transient users who are not exposed to communications by mail, newspaper, or broadcast.

The drinking water regulations require notifications to be presented in a manner that:

- Fully informs users concerning system non-compliance
- Is conspicuous, understandable, and not overly technical
- States all facts regarding the nature of the problem
- Includes, where appropriate, the MCL or regulation that has been violated
- States appropriate measures to be taken by consumers in order to protect their health
- Does not result in undue concern by the public

Notifications are recommended to explain the significance of the problem, the steps taken by the water supply to correct the deficiency, and the results of additional samplings.

The SDWA also includes provisions for obtaining exemptions or variances to alleviate major difficulties in meeting regulations. These provisions recognize the technical, time, and financial constraints in meeting requirements of the act. The exemption is a procedural mechanism that allows the State and/or EPA to provide additional time for a public water supply to come into compliance. This procedure gives the public water supply one year to devise a schedule whereby it must come into compliance with the SDWA by January 1, 1981, provided no immediate health risk would result during that period. The exemption allows communities to assess their situation, seek funds, complete the necessary engineering, etc. Additionally, for systems seeking to regionalize, another two years, i.e., January 1, 1983, was provided to allow for the negotiations that would be required. Variances were designed for situations where communities have exhausted their options to come into compliance. The intent was to protect from a citizen suit, water systems which had applied the best available technology and still could not comply with the provisions of the SDWA (provided no immediate health risk was present). It should also be clear that the exemption and variance do not give a license for non-compliance. It merely protects the public water supply from suit until such time as compliance can be achieved.

Several sample notices are presented in the EPA "Public Notification Handbook" as referenced at the end of this section.

EPA has promulgated Secondary Standards which deal with the aesthetic qualities of potable water. These Standards are summarized in Appendix C. They are not Federally enforceable, and are intended as guidelines for the states. Poor aesthetic quality of public water supplies has no direct health effects, but may indirectly affect health by causing people to seek drinking water which tastes, looks, or smells better, but which may pose a higher health risks.

Rationale For National Interim Primary Drinking Water Regulations

The rationale for the NIPDWR is summarized in Appendix F. This table gives the health effects of each contaminant, the basis for establishing the MCL, and the sources of the contaminants. Further details along this line are given in the information published in the Federal Register and also in the 1973 report of the EPA Advisory Committee on the Revision and Application of the Drinking Water Standards.

Cost effects as well as health effects were taken into consideration in establishing the Primary Regulations. There are no further trade-offs between costs and health risks to be made. The Standards are already minimum with respect to health considerations. In cases where the health effects are well enough established to determine accurately the safety factor provided (as indicated in Appendix F), the safety factor is the minimum with respect to health safety. Most of the MCL's apply to people of all ages, however the nitrate MCL is to protect infants under 6 months of age against infant cyanosis or "blue baby" condition, and the fluoride MCL is to protect the teeth of children during their years of tooth formation.

Secondary Standards

As already mentioned, these proposed Standards are summarized in Appendix C. They concern aesthetic qualities of potable water. They are not Federally enforceable but may be by the State if they so desire. The possible trade-offs between cost and conformance with the secondary standards, then, is a matter of what is permissible under individual state requirements.

Options For Meeting the Primary and Secondary Standards

Information on these options is presented under Section 8, Treatment Objectives, of Part 2, PRODUCTION. In addition to the installation of the treatment facilities needed to reduce contaminant levels to acceptable limits, there are other possibilities. One possibility would be to develop a new source of supply of better quality. Another would be to purchase water from another system which has available water of acceptable quality. If technical assistance is needed in considering these options, it might be obtained from a consulting engineer, from the State Water Quality Agency, or from EPA where the state has not assumed primacy. The U.S. EPA, Cincinnati has published a "Manual of Treatment Techniques For Meeting The NIPDWR" in May 1977, as referenced at the end of this Section.

LEGAL RIGHTS AND LIABILITIES

The operation of community water supplies involves legal rights and responsibilities. All public waterworks, whether publicly or privately owned, are legally recognized as governmental activities. They maintain the right of eminent domain and the authority to condemn private property for water supply needs.

In some states, depending upon enabling legislation, utilities also have special rights associated with providing water service for fire protection. Water utilities have the right to discontinue service if a hazard to the governmental regulation as deemed appropriate for maintaining public service; therefore, regional provisions of this type should be consulted. Nevertheless, public water supplies are not protected against damage which is incurred through their own negligence. This point may become increasingly more important with the advent of the SDWA. The act defines specific water supply regulations to be met, providing a mechanism whereby a utility can be challenged for negligence when in non-compliance. It is important for utility management to be cognizant of these possibilities and to avert such citizen legal actions by maintaining compliance with approved state and federal reporting schedules and regulations. Waterworks may also be sued for negligent operations that result in personal injury or property damage.

Water rights law may have considerable influence in the selection and development of new or augmented sources of water supply. Depending upon the state having jurisdiction, water rights laws may apply to either groundwater or surface water, or to both. Water rights determinations often rest more on case law than statutory law. Although municipal water use generally has the highest priority of all beneficial uses of water, there are great variations in water law. The differences have developed or evolved as a result of widely different climatic and geographical conditions which affect water supply and water use across the U.S. Water rights laws are so diverse and so complex that it is not possible to summarize all of them here. The best advice that can be given is to recommend to water works officials that they contact their State water rights administrator or an attorney who is experienced in the water rights law which prevails in the case under consideration. This is a highly specialized field, and a person who is an expert on one State's water laws may not be able to advise in other areas with different laws and water conditions.

PUBLIC RELATIONS & PUBLIC NOTIFICATIONS

Public relations have always been an important part of water supply management. Recently good customer relations have assumed even greater proportions because of the environmental and consumer movements and due to increased public participation in all public affairs and utility matters. A well informed public can greatly assist utility projects, while an uninformed public can effectively stop almost any project however deserving it might be. There are many ways to inform the public and obtain citizen support. One method is to form a Citizen's

Advisory Committee to work with water system management and administration. Hearings for public participation early in project formulation are important. A public that is promptly and accurately informed during periods of normal utility operation is much more likely to be helpful during emergency periods and other difficult times for the water department.

Some potential benefits of an effective public relations program are:

- Greater consumer support for improving water system facilities
- Better public decision-making regarding increasing revenues, levying taxes, and voting on bond issues
- Improved employee attitudes and working conditions through pride in community service
- Better public response to Public Notifications when such notification becomes necessary
- Overall improved operations
- Allows the utility to clarify its position

Public relations programs may be different for small and large utilities. However, the goal is the same - to inform the public and to secure public cooperation in the water programs. Large utilities may have special public relations staff, but in every case all employees must assist in this effort. They can do this by the way they conduct themselves on the job and in the community and by being alert to every opportunity to let the public know what the utility is doing and what its future plans are.

The public notification requirements of the SDWA are intended to secure public assistance in providing necessary water improvements by making all water customers aware of existing water works deficiencies and their potential effects on public health. The minimum notification requirements might well be supplemented by public meetings, newspaper articles, billing leaflets, and open discussions of water works problems and potential solutions.

ECONOMIC AND ENERGY TRENDS

The current, rapid inflation rate and changes in the nation's economic structure due to depletion of our natural resources have placed added pressures and responsibilities on water supply management. These external influences are more apparent for large utilities. It is, therefore, important for respective managers to be cognizant of the changing energy and economic trends which may directly influence future planning and operations. Substitute energy sources and all other mitigation measures should also be carefully reviewed in advance of expected needs for change. Water conservation methods should be studied. The possibility of pumping water at times of off-peak electrical demand, by utilization of storage, should be investigated.

The costs of raw materials may also influence future use. Many chemicals, such as chlorine, are highly energy intensive and, therefore, can be expected to increase in cost proportional to increasing energy costs.

REFERENCES

- "The Safe Drinking Water Act, Self-Study Handbook; Community Water Systems," AWWA, 1978. Explains the requirements of the SDWA, including quality regulations, performance testing, and public notification procedures.
- "Water Utility Management," AWWA Manual M5. Chapter 3 deals with the legal and moral responsibilities of a water purveyor. Chapter 21 deals with public relations with respect to water utilities.
- "Technical Guidelines for Public Water Systems," U.S. EPA, June 1975, NTIS #P 255 217. Chapter 8 includes a section on customer relations.
- "Public Notification Handbook For Public Drinking Water Supplies," U.S. EPA Office of Drinking Water, Washington, D.C. 20460, May 1978.
- "Report of the EPA Advisory Committee on the Revision and Application of the Drinking Water Standards," EPA, Washington, D.C., 1973.
- "Manual of Treatment Techniques For Meeting The IPDWR," U.S. EPA, 26 W. St. Clair Street, Cincinnati, Ohio 45268, (EPA-600/8-77-005), May 1977.

PART II

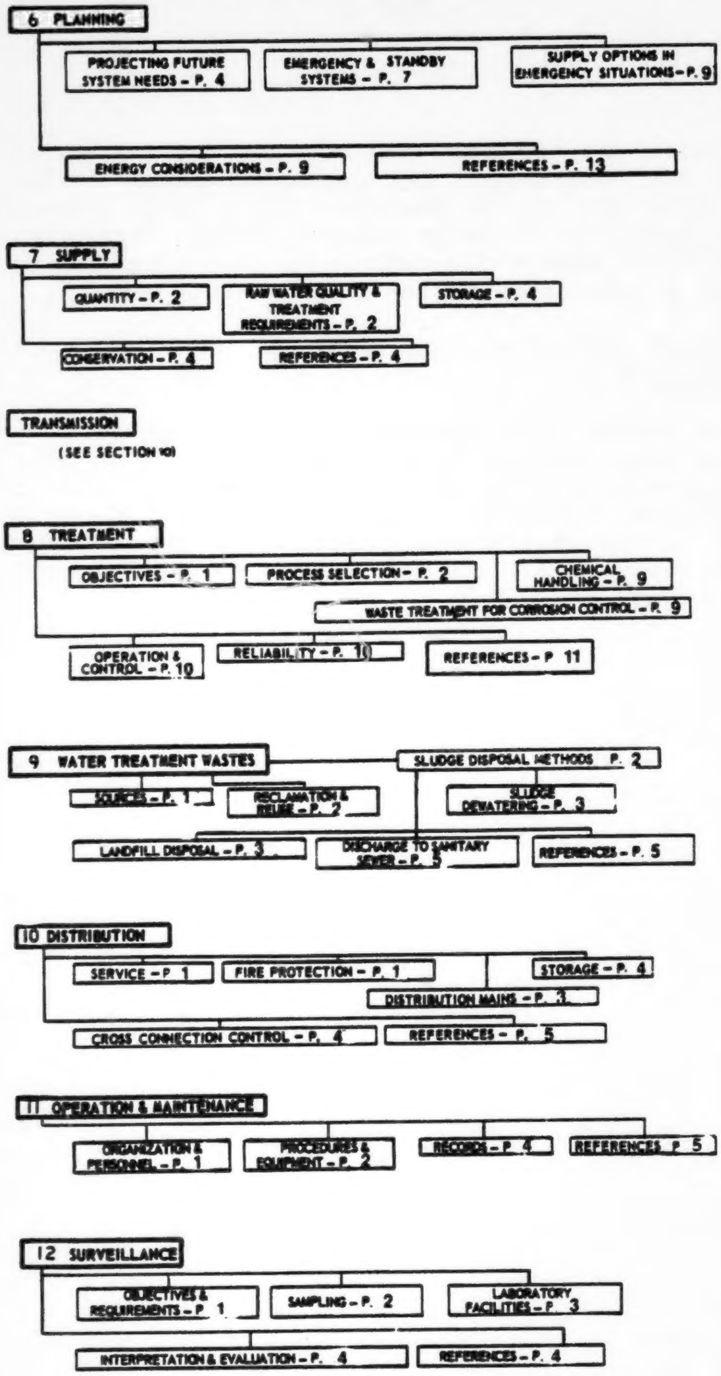
PRODUCTION

The production of potable water spans a broad range of activities which are likely to become more complex with the increasing demands being placed on the water purveyor. This part of the decision-maker's guide addresses the common aspects of water production including planning, supply, transmission, treatment, and distribution. Other aspects of potable water production dealing with disposal of treatment plant wastes and operations are also discussed.

Water production activities from source of supply to consumer are shown graphically by Figure 6 -1.

The nature of potable water production is usually specific to each facility. The information in these sections is presented as a guide to help the decision-maker obtain an overview of water production, which should be helpful in identifying the strengths and weaknesses of the water system. For specific problems it may be advisable to seek help from a consultant. A reference list is included with each section for obtaining specific information regarding the problem areas identified in this overview.

PART II PRODUCTION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SECTION 6

PLANNING

There are several questions which can be posed to aid in consideration of water system planning:

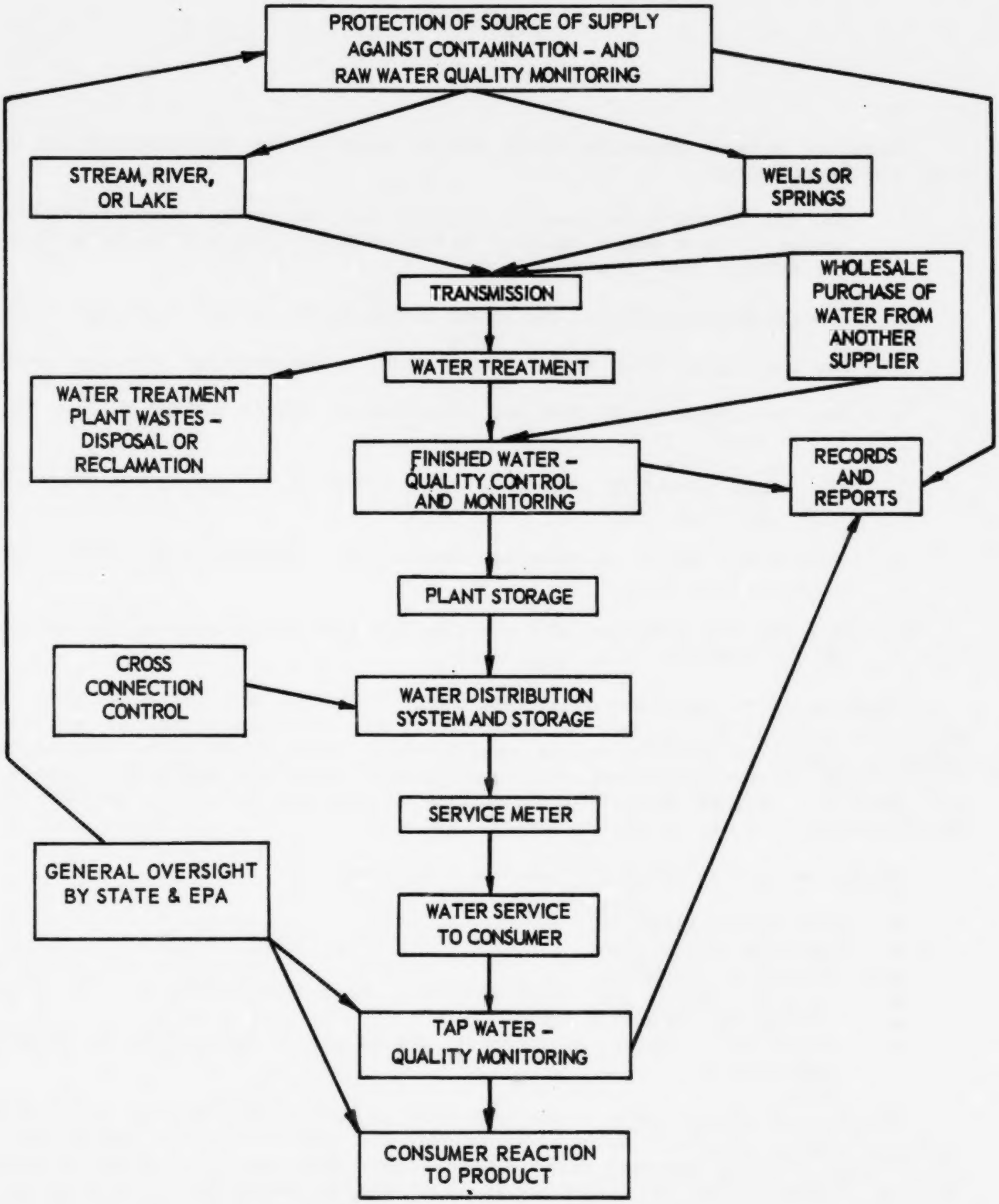
1. How can planning be used to provide the new water works facilities needed to meet water quality requirements of the Safe Drinking Water Act (SDWA)? (See this page below)
2. How can future needs of the water system be projected? (See page 6-5)
3. How can needed water works improvements be implemented? (See page 6-6)
4. What emergency conditions may affect water system planning? (See page 6-7 to 6-10)
5. What plans should be made to provide necessary redundancy and reliability? (See page 6-12)
6. What plans should be made for conservation of water and energy? (See pages 6-10 to 6-12)
7. How does the water utility planning fit into the overall growth pattern of the community? (See page 6-7)

Planning is an important management activity of all waterworks systems. The utility's planning policy may reflect general goals of the community and surrounding regions in addition to the specific objectives of the water department. Interactions between government and community activities are important; moreover, any practical program should be formulated within the financial, social, and regulatory constraints of the community.

There are several levels of planning including:

- Area master plan
- Sub-area master plan
- 201 and 208 planning
- Project planning and interfacing with other agencies
- Capital improvement plans
- Concurrent planning, replacement, and repair or reinvesting to offset depreciation

Plans which affect water works operation to varying degrees are prepared by Federal, state, regional, county, municipal and other agencies. Historically, water works planning has been based almost solely upon providing unlimited water service to the public as needed. This practice was based on the unquestioned responsibility of the water utility to meet the water service needs of the area served under all conditions. Recently, water works planning has been modified to take into account a number of political questions which cannot be ignored. Such


PROTECTION OF SOURCE OF SUPPLY AGAINST CONTAMINATION – AND RAW WATER QUALITY MONITORING
STREAM, RIVER, OR LAKE
WELLS OR SPRINGS
TRANSMISSION
WHOLESALE PURCHASE OF WATER FROM ANOTHER SUPPLIER
WATER TREATMENT
WATER TREATMENT PLANT WASTES – DISPOSAL OR RECLAMATION
FINISHED WATER – QUALITY CONTROL AND MONITORING
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PLANT STORAGE
CROSS CONNECTION CONTROL
WATER DISTRIBUTION SYSTEM AND STORAGE
SERVICE METER
GENERAL OVERSIGHT BY STATE & EPA
WATER SERVICE TO CONSUMER
TAP WATER – QUALITY MONITORING
CONSUMER REACTION TO PRODUCT

Figure 6-1. Water Production Activity

considerations include land use planning, growth control, wastewater planning, the goals and plans of other local, state, regional, and Federal agencies, and public desires.

Planning is the continuous process of assessing utility operations and short- and long-term water supply needs and facility operation. Good historical records of community growth and existing facility operations are important for accurately assessing community needs. This fact should be considered in general plant management. Comprehensive development plans are generally required for projecting long-term supply needs, especially for large utilities. Comprehensive planning programs will vary among communities depending on size, local regulations, local customs, and available technical assistance. The general process for formulating major policy should include the following steps:

- Outline supply goals and non-supply interests
- Evaluate and analyze program alternatives
- Prepare short- and long-term plans
- Implement plans, assess the program and its interactions and provide feedback for future actions or planning

The managers of a water supply system are not solely responsible for formulating departmental master plans. Planning is an integrated process that involves other departments, city or community leaders, operations personnel, and community interaction. In this regard, it is the duty of a water supply administrator in the planning process to:

- Collect and evaluate available information
- Transmit information to other departments, community leaders, and the public
- Promote community interest in policy making
- Coordinate inter- and intra-departmental activities relative to plan development and implementation
- Consider compatibility with regional plans and land use plans
- Promote projects or establish priorities that satisfy goals and oppose objectionable policies
- Implement approved projects

The major concerns of a comprehensive water supply plan include projecting future system needs, evaluating emergency and standby systems, and assessing changing regulations. The quantity of water available from the source of supply and its long term quality are most important.

PROJECTING FUTURE SYSTEM NEEDS

Estimates of future water demand represent the basis for sizing water system facilities. The design period for such predictions depends upon the nature and permanence of the structures and the cost of capital financing. An equitable division of the financial burden among present and future consumers suggests provisions be made for 10 to 30 years in advance of the present requirements. The typical design period for distribution systems and surface supply works is 50 years; for treatment facilities, a ten to 25 year planning period is generally used.

It is increasingly difficult to build water impoundments, so classical approaches to water supply design may have to be supplemented by consideration of other measures. For example, in planning sources of supply, it may be necessary to decide whether to design raw water storage for a 100-year drought, or whether it may be possible by special conservation measures during drought periods to design source storage for a less severe drought condition.

Water demand estimates are based on population projections, commercial and industrial growth, water use trends, climate, metering, extension policies, and changes in service area boundaries. Detailed predictions may be developed by summing the projected domestic use, commercial use, industrial use, fire demand and other municipal uses and loss due to unaccounted-for water (typically 10 percent of average use). Unaccounted for water includes leakage, water for fire fighting, street flushing, and use by the water system and the City for main flushing, bearing cooling, and meter testing. Commercial use is ordinarily related either to number of employees or gross area for each specific enterprise. Similarly, industrial demand may be estimated per unit of production.

Fire demand is an important component in system sizing. The local fire department and local fire insurance agents can supply information on the rating system used in the community and the fire flows required in different areas. The flow requirement for fighting fires, even in a residential area, may necessitate considerably larger mains than the domestic demand alone. In some cases, it is not feasible to provide full fire flows in the initial stages of plan development; however, since the life of distribution mains is generally in excess of 50 years, it is wise to install mains that are sized to convey the future fire flows so they will not have to be replaced at a later date. High service pumps, distribution mains, and treated water storage facilities are sized to meet the larger of peak hourly demands or fire requirements plus average demands of the maximum day. Reliable metered data is requied to arrive at maximum daily flows and peak hourly flows which are needed for design purposes. In the central city, waterfront areas, or industrial sections dual (domestic and fire) water distribution systems may be advantageous.

Population forecasting is the most important component in estimating future water supply needs. Population data may be available from local or state planning agencies. Many methods have been developed for estimating the size and make-up of the households to be served by the water-providing agency. The size and household make-up of future residents of any service area will be influenced by potentially complex demographic, economic and land use factors. If conditions with regard to these factors within the service area and the economic region are not changing, but are static, then historical data on population can be used to extrapolate the past into the future in order to project the make-up and size of residential water users and estimate their future demands for water. But if any of these conditions are dynamic, which means that they are changing or are likely to change in the future, then the nature of those changes has to be analyzed and their interactions considered in order to forecast future water demands from households.

Appropriate Projection Techniques For Static Conditions

If economic, demographic and land use influencing conditions are static, population projection is appropriate. The following methods are frequently used:

- Arithmetic increase method assumes the rate of population growth remains constant. Projections are made by linear extrapolation of historical growth into the future.
- Geometric increase projections may be employed for rapidly growing communities. In this case, the growth rate is assumed proportional to population size following an exponential pattern, i.e., a constant percentage of growth is assumed for equal time periods.
- Declining-rate geometrical increase is a modification of the geometric forecasting method which assumes a declining rather than a constant proportionality with population size.
- Comparative projections are based on the growth patterns of several larger cities with similar commercial, industrial and population characteristics to the community in question. Growth records of the analogous communities are used for predicting future population growth.

Appropriate Projection Techniques for Dynamic Conditions

If demographic, economic and land use conditions are dynamic, population forecasts are frequently derived from estimates of changes likely to result from:

- Natural demographic changes (births, deaths and new household formations)
- Net migration and
- Housing market and development changes

Unless the nature of the service area is such that most of those who work in the area also live in the area, the assessment of natural demographic changes and migration is usually performed on a regional basis. Then housing market and development assessments are considered to allocate appropriate portions of the regional population to the service area.

Natural demographic changes are most freqently forecast using a cohort-survival method, to project changes in specific parts of the present population. In most cases, the existing population is categorized by age and sex. Changes in these two groups are then forecast on the basis of estimated survival rates, fertility rates, and new household formations. Natural demographic changes can be forecast with the judgmental extrapolation of historic trends.

Migration in and out of the region or service area (if the service area is large enough so that it includes the work places of its residents) is usually forecast by linking migration rates to forecasts of future employment. Employment in various sectors of the region can be forecast by various economic techniques. Frequently, the techniques draw upon the historic relationship between population and the growth of jobs in the region. Judgments concerning the comparative advantages of the region for various kinds of economic activities can also be used to forecast future employment. Frequently too, employment forecasting begins by estimating future jobs in basic industries (those that export goods or services from the region), followed by estimates of the future for local population-serving businesses.

By whatever means changes in the economic base of the region is forecast, the link between jobs and population is made through the estimation of labor force participation rates. Estimates of these rates permit the forecaster to judge the number of employed households likely to be attracted to the region by the jobs available in future years, and the number of households in the work force likely to migrate away from the region.

Housing economics, (including the availability of buildable land and the relative demand for housing locations in the service area) have to be considered in order to estimate future housing development options and the likely occupancy of present dwellings. Land use plans, transportation plans, and appropriate housing development regulations also are considered in light of the likely housing economics in order to estimate future housing availability in the service area. If the service area is smaller than the region, the forecaster must allocate a share of the region's future household population to the service area.

Project implementation is an important management function. A comprehensive program for the water department should be integrated with other community needs and financial requirements. A common developmental approach provides the system components of the ultimate plan that are immediately required, or are not well suited for staged development, in the initial construction phase. Remaining facilities can be added in phases as they are needed. This approach minimizes the initial investment and financial burden on the existing customers. Another approach involves a gradual development through construction of independent treatment units as needed, thereby distributing financing over an extended period. In either case, the planning program involves a continuous assessment and reassessment of system and community needs. Water planning must be coordinated with sewer system planning.

In order to provide lead time for construction, system expansion is indicated when the demand approaches not more than 80 percent of the rated capacity of installed facilities. For major capital improvements, the lead time should be sufficient to allow for engineering investigations and design, environmental impact analyses, financing, and construction.

EMERGENCY AND STANDBY SYSTEMS

The water supply system is a vital community service in many ways. This must be considered in facility planning. Power failures, equipment breakdowns, routine servicing requirements, distribution line failures, and severe fluctuations in the quantity and quality of supply are periodic occurrences in all water supply systems. In addition, certain regions may be subject to violent storms, hurricanes, flooding, earthquakes, strikes, or other natural or man-made disasters that could disrupt operations. Vulnerability assessment is a very important part of planning for emergencies. The impacts of such problems can be minimized through flexible system design and development of emergency programs in advance of the need.

Reserve capacity, storage, and system flexibility contribute greatly to system reliability, especially for small systems. Treated water storage should provide service during the time needed for plant repairs if treatment facility duplication is not practical.

Whenever possible, dual units or multiple water supply and treatment trains should be provided. Overall system reliability can be improved significantly by augmenting surface water supplies with groundwater sources when possible. Duplicate basins, equipment, and pipelines may be needed for continuous operation. Auxiliary power units should be installed to maintain minimum standby services, particularly in those systems not having a large reserve storage capacity. High service pumping stations, treatment plants, and wells that pump directly into distribution systems should be equipped with standby power. Emergency power should be designed to produce and deliver average daily water demands.

Water systems that employ direct pumping into transmission mains without storage are extremely susceptible to equipment malfunctions and power outages. Multiple pumps should be used in this case. Recommended practice is to provide three pumps of equal capacity where any two can deliver the peak demand.

Design of distribution systems also is important for assuring supply reliability. Multiple transmission mains and looped-grid distribution patterns provide desirable system redundancy.

Reliable water service can also be assured through effective system maintenance and emergency training programs. All personnel should be well versed in appropriate emergency plans and the importance of preventive maintenance. This requires periodic training sessions directed at these specific objectives.

The American Water Works Association (AWWA) recommends the personnel requirements for meeting contingency plans as outlined in Table 6 -2. Obviously, allocation of the listed duties will vary according to system size and complexity. Likewise, emergency training needs will vary for specific community needs.

TABLE 6-2. RECOMMENDATIONS FOR CONTINGENCY PLAN PERSONNEL REQUIREMENTS

	Management	Engineering	Operators	Chemists	Maintenance - Plant	Maintenance - Field	Police or Security Force	Radiological Monitor
Vulnerability analysis		x	x					
Protective design		x						
Utility liaison	x						x	
Security	x						x	
Hazard assessment		x		x				x
Personnel safety	x						x	x
Emergency operation	x	x	x	x	x	x		
Emergency repairs		x			x	x		

Source: "Emergency Planning for Water Utility Management", AWWA

An ongoing training program is essential to ensure effective service in the event of major system upsets, especially for small communities. The objectives of an emergency planning program should be clearly outlined, and specific duties established and posted to eliminate confusion during unusual situations.

SUPPLY OPTIONS IN EMERGENCY SITUATIONS

States assuming primacy under the SDWA are required to develop a State Emergency Plan. Historically, in water works operation, the two most common and most disastrous types of emergencies have been drought and flood. The kinds of water system failures which are likely to occur during drought and flood are rather well documented (see last two references at the end of this section) and generally can be planned for in advance.

Drought. The San Francisco Bay Area encompasses one of the most complex and extensive water conveyance systems in the world. Some valuable lessons were learned here during the 1976-1977 drought. Water needs were met by a combination of supply augmentation and demand reduction.

Supply augmentation was accomplished by use of emergency surface supplies, use of dead storage, development of new wells, activation of old wells, broader utilization of treated wastewater, leak detection and repair, construction of temporary pipelines, and water hauling.

Demand reduction through rationing played a key role in getting through the drought. Both mandatory and voluntary rationing were employed. Reductions in water use were as great as 45 percent by apartment dwellers and 75 percent by single family residences.

Flood. There are numerous examples of flood damage to public water supplies, but the Kansas River flood of 1951 probably had as many serious and prolonged effects as any. Analysis of water supply failures in 37 cities showed the most frequent causes were; power failure, flooded wells, flood treatment plants, distribution system damaged, and low lift pump station flooded. The emergencies were met by providing temporary emergency power by means of portable generators, portable water purification units, improvised mutual aid among neighboring cities, water hauling, volunteer labor, water conservation, emergency communication by radio, and coordination of activities by state and Federal agencies. Good records of valve location, and plans and maps of water distribution lines were valuable tools in the restoration of water service.

ENERGY CONSIDERATIONS

The present importance of energy conservation may make it advisable for many water systems to employ engineering consultants to advise them in this regard, including special system studies and reports. Recent shortages and the high costs of electricity, fuels, and chemicals have become important considerations in water system planning. The need for instituting energy conservation measures will become increasingly apparent as traditional fuel supplies dwindle and associated costs rise. The cost of energy will be felt indirectly in the availability of consumable products. The cost of chemicals (alum, lime, polymers, and chlorine), which are essential for water treatment, have increased in past years and will continue to do so as the energy required for their production becomes more expensive. This fact reinforces the need for the consideration of energy requirements in water system planning.

Means for reducing energy costs are alternative sources development and water and energy. These methods are easily incorporated in new facilities; however, retrofit modifications to existing facilities may often be feasible. More water storage may permit water pumping to be done at off-peak periods of power use. During periods of peak power consumption flow into the water distribution system could be by gravity from storage. Another means of energy conservation is through reduction of unaccounted-for water through leak detection and repair.

During the design of water system improvements, if there are options, consider energy requirements. The economics and trade-off between capital and O&M costs are changing. If possible provide sufficient storage of water so that pumping can be done at off-peak times. Give attention to increasing storage in elevated locations versus storage that which requires repumping.

Sources

The traditional sources of energy for water supply are electricity, natural gas, and fuel oil. As energy demands and consumption increase, these sources of energy will become more scarce and costly. Alternative means of supplying part or all of the power needed for water works may be appropriate in the future.

Solar energy for building heat is a possible substitute for gas heating. Solar collectors can be retrofitted at reasonable cost and may represent a substantial energy savings for small or simple systems. A heat pump is also an effective device for space or water heating. The effectiveness of utilizing heat pumps is dependent on the size of the system and the total energy demands.

In determining the type of energy to be used for water systems, the future availability of energy under the particular local conditions should be analyzed.

Conservation

With energy costs for water supply, treatment, and distribution being projected by experts in the field to double or triple within the next ten years, programs to reduce consumption deserve attention. Energy consumption at existing facilities can be reduced by improving pumping efficiency. The design of new facilities should include study of the potential means for minimizing electricity and fuel demands.

Pumps should be operated at the highest efficiency possible. This may require some system modifications, a change in operations, and the repair of existing mechanical equipment. A thorough examination of the existing system and a cost-effectiveness analysis will indicate the areas where pumping changes will be most effective in reducing energy use. Some aspects of operation which may reduce pumping energy include:

- More frequent pipeline cleaning to reduce friction and increase the effective diameter of existing pipes
- Better utilization of storage so pumps are operated more uniformly for longer times and at lower heads
- Use smaller pumps rather than oversized ones which require throttling to suit system conditions with waste of energy
- Having all valves completely open during pumping
- Off-peak pumping
- Treatment of water for corrosion control to reduce friction losses in pipelines
- Make use of variable speed pumps

Minimizing energy consumption should be considered in planning and implementing system improvements and expansions. Possible trade-offs which reduce energy should be analyzed on an overall cost-effectiveness basis including operation and maintenance, not merely on a capital cost basis. Additional considerations include the following:

- Increasing transmission and distribution line diameters to reduce friction and therefore pumping head, with due consideration to the cost of larger pipe. Energy requirements increase as the 1.85 power of the head loss.
- Comparing different pipe materials to minimize friction and pumping head
- Investigating alternative source locations and different raw water treatment needs to optimize delivery and treatment costs
- Comparing various storage alternatives such as raw water, treated water, and distribution storage
- Evaluating fixed versus variable speed pumps and optimizing pumping schedules
- Comparing various treatment processes to produce the highest quality product for the least cost (including use of chemicals that minimize the quantities of energy used for manufacture)
- Utilizing dual distribution systems where advantageous
- Utilizing heat recovery systems in lime recalcination and carbon regeneration systems

- Computerizing process and distribution controls to maximize treatment efficiency, minimize chemical consumption, and stabilize pumping operations

- Reclamation and reuse of water for appropriate purposes in situations where this saves energy

Energy conservation is highly system specific. What may be effective for one system or set of conditions, may not be for another. Each energy conservation program should be carefully studied to make sure it will actually reduce energy consumption.

The preceeding discussion has centered around energy conservation rather than around water conservation. This was done because fossil energy is a limited non-renewable resource, while water is a renewable resource. Water is renewed in the natural hydrologic cycle, or it can be renewed by man through application of proper treatment. One way to save energy is to use less water. However, there are many situations where water conservation, per se, is vital. One of the foremost is in areas of groundwater "mining", that is where the total use from an aquifer exceeds the average rate of recharge of the aquifer. Water conservation during drought, as already pointed out, may also be practiced to reduce capital expenditures required to maintain normal water consumption rates.

In times of drought, water demand management can be exerted by: adjusting rate structure, installation of water conservation devices in homes, conservation education, and rationing.

Redundancy and Reliability

Public health and economic considerations of public water supply dictate that a reliable source of high quality water be provided to meet reasonable customer demands. This means that even under emergency conditions, operations must continue. A certain amount of redundancy is provided in supply and process equipment to ensure reliable service under emergency conditions. The same must be true of the power and fuel sources.

The standby power requirements will, of course, be dependent upon the size of the system and the minimum equipment needed to provide services. Facility design should provide two independent sources of power for all essential mechanical and electrical equipment. Depending on the location of the facilities, an on-site auxiliary generator or a second independent electric service line may be appropriate. Adequate distribution storage may also be used to ensure service under emergency conditions. The standby power supply need only be adequate to operate essential mechanical and electrical equipment (lights, pumps, etc.), not necessarily all facilities (air conditioning, etc.).

The operations staff should be thoroughly familiar with emergency plant operations. Standby power equipment or service should be checked and operated periodically to be sure that it is fully operational in the event of an emergency. Fuel reserves should be used sparingly in case of an extended energy shortage.

Use of treatment chemicals should be optimized. A 30-day supply of chemicals should be kept at the treatment plant since a widespread energy crisis may limit chemical production, or strikes may occur, making delivery schedules unreliable.

The less dependent on energy a system is, the easier it will be to operate under emergency conditions or if the nation's energy reserves become seriously strained. Redundancy of power supply is important in the design of water systems to provide reliable service. Equally important, however, is minimizing the basic system demands for energy, both primary and secondary. Energy conservation and system reliability are compatible.

REFERENCES

- "Emergency Planning for Water Utility Management," AWWA Manual M19. Gives positive guidelines for the development of emergency plans, including disaster effects, vulnerability assessment, protective measures, emergency operations planning, and training.
- "Technical Guidelines for Public Water Systems," U.S. EPA, June, 1975, NTIS #PB 255 217, Chapter 1 gives general guidelines for planning a water system, including general considerations, capacity sizing techniques; treatment requirements, distribution systems and appurtenant facilities.
- "Energy Conservation in Municipal Wastewater Treatment," U.S. EPA, MCD-32, March, 1977. Contains curves to determine energy demands for unit wastewater treatment processes, many of which are applicable to water treatment; also describes energy saving measures such as solar heating, furnace heat recycling, etc.
- "Operation of Wastewater Treatment Plants; A Manual of Practice," WPCF, MOP 11, 1975, Chapter 28. Discusses energy conservation practices in wastewater treatment, some of which are applicable to water supply systems.
- "North Marin's Little Compendium of Water Saving Ideas," John O. Nelson, March 1977, North Marin County Water District, Novato, CA 94947.
- "Interruptions To Water Service By The Kansas Flood of 1951", D.F. Metzler and R.L. Culp, JAWWA, p. 780, Sept. 1952.
- "Urban Drought In the San Francisco Bay Area: A Study of Institutional and Social Resiliency", M. Hoffman, et al, JAWWA, p. 356, July 1979.

SECTION 7

SUPPLY

Selection of the source of supply affects many parts of the total water system, so that it is important to ask several questions in order to optimize the source selection process.

1. What are the primary features to consider in selecting a source of water supply? (See pages 7-1 and 7-2)
2. How are future quantity requirements estimated? (See page 7-2)
3. What are desirable raw water quality characteristics? (See page 7-2)
4. Is raw water storage needed? (See page 7-4)
5. What benefits accrue to source of supply from water conservation? (See page 7-4)

The raw water source of a waterworks influences the overall system design, operation, and management in many ways. For example, specific characteristics of each source may affect the available yield, treatment requirements, operations, and the ultimate water quality that reaches the consumer. Some of the primary considerations for evaluating the characteristics of a particular water supply are:

- Water quality
- Treatment requirements and cost
- Environmental concerns
- Safe yield
- Location
- Economics of development
- Water rights and long-term availability
- Energy use

Source requirements are specific for each community, being a function of the geography, topography, hydrology of the watershed, and the community size. Groundwater sources are generally preferred when available in sufficient quantity since they typically are of higher quality and, thus, require less treatment.

Except for some springs and artesian wells, most groundwater sources require pumping. The raw water storage provided by groundwater aquifers is advantageous. In warm months, the temperature of groundwater is generally lower than that of surface waters in the same general location.

Surface waters are the principal source of potable water in the U.S. because they generally are available in larger quantities than groundwater. In mountainous areas, surface waters collected or stored in high areas can often be transported and distributed by gravity flow to the points of use. However, the comparative availability of ground and surface waters varies greatly from place to place. There are many regions in the U.S. where only one or the other (ground or surface) supply is available in quantities which permit practical development.

In areas where water supply is short or of poor quality requiring extensive treatment, or where there are nearby sources of supply already developed by others, it may be prudent to consider the purchase, on a wholesale basis, of raw or treated water from another purveyor.

QUANTITY

The delivery capacity of a waterworks supply source should exceed anticipated demand for a reasonable time period in the future. A reasonable design period for wells may be 5 to 10 years, for small surface supplies 10 to 25 years, and for large surface supplies involving long construction times may be 25 to 50 years. Safe yield for a water source to meet annual average demands is calculated for 50- to 100-year drought conditions. The supply should be assessed using the best hydrologic information available for the watershed. If adequate records are not available, estimates may be performed by various methods using local precipitation records. The U.S. Geological Survey and U.S. Weather Bureau may be consulted for this information.

An impounding reservoir or some other means of storage is required when minimum stream flows do not meet maximum daily demands. A complete water budget should be prepared for determining the safe yield. Water balance computations employ all important stream records, runoff information, and include calculations for surface evaporation and loss due to seepage. For extreme drought conditions as much as 4 years of carryover storage may be required. As already mentioned, conservation may reduce storage needs for drought.

The safe yield from well water supplies should meet maximum daily demand with the largest well out of service. The yield from each well can be estimated from pumping tests, well location and construction, and the minimum static water level and minimum groundwater level permitted during drought conditions. Drawdown of existing wells should be checked and recorded periodically for future projections of supply needs. A basin-wide groundwater management program may be advisable to prevent overdraft and excessive drawdown during drought.

RAW WATER QUALITY AND TREATMENT REQUIREMENTS

The raw water quality is an important consideration in overall system performance and economics. The treatment plant requirements are a direct function of source water quality and the required product water quality. A sanitary survey by qualified personnel is required to assess the applicability and treatment needs for each specific water source. A sound policy is to use the highest quality water source available in order to minimize treatment and the potential risk to consumer public health. Cost, environmental effects, and reclamation potential are other factors to be considered.

General characteristics for ground and surface waters are listed in Table 7-1. Certain groundwater sources may contain high amounts of dissolved inorganics which may necessitate treatment to achieve acceptable water quality. On the other hand, surface waters are exposed to contamination and may vary in

TABLE 7 -1. GENERAL CHARACTERISTICS OF WATER SOURCES

Source	Type	Comments
Groundwater	Springs	Quality and quantity are functions of water-bearing strata, shallow springs are often susceptible to surface water contamination.
	Well	Uniform quality, low turbidity, good bacteriological quality
	Infiltration galleries	Typically "hard," containing many dissolved inorganics
	All	May contain trace organic substances
Surface water	Streams, rivers, and lakes	Exposed to surface contamination
		Variable quality and quantity
		Typically "soft," containing few dissolved salts or inorganics
		Variable turbidity
		Variable or questionable bacteriological quality
		Many organic impurities with associated color, taste, and odors
		Usually requires more treatment than groundwater

quality due to storms, seasonal changes, excessive runoff, etc. In order to maintain a high quality product water under variable raw surface water conditions, a flexible treatment scheme is necessary, and process operation must be monitored regularly and adjusted according to prevailing conditions. All source waters, ground or surface, should be properly protected from contamination that will adversely affect plant operations and product quality. This requires careful consideration of the source of supply location relative to potential contaminant sources.

STORAGE

Source of supply storage facilities should be provided to meet water demands under extreme drought conditions (50- to 100-year drought). Under severe conditions four years of carryover storage may be required. Furthermore, the overall capacity of the watershed reservoir (ground or surface) should be assessed intermittently to determine the long-term adequacy of the source. If the average reservoir demand is greater than its rate of replenishment, then the system will not meet the long-term needs of the community. Long-term source depletion may also result in unexpected contamination from adjacent water systems, such as saltwater reservoirs which can destroy a supply source with little advanced warning. A good indicator of source contamination of this type is the trend of raw water quality over an extended time period, and the quality changes in monitoring wells.

CONSERVATION

The production and distribution of potable water is a capital- and energy-intensive activity. Accordingly, there has been increased interest in the potential benefits which may be realized by consumer water conservation. This interest is due to competition for supply sources, escalating costs for energy and energy-intensive chemicals and materials, and the increased production costs associated with the need for higher quality water. The useful period of a water supply system for meeting community demand may, in some cases, be extended by increased efficiency in water use. This may represent a major cost savings in certain cases, especially if the cost of developing additional or new water supplies is very high. Water conservation should be considered by all water utilities in water-short areas to save water, and in all areas where pumping is involved to save energy.

REFERENCES

- Water Supply and Wastewater Removal, G.M. Fair, et al, John Wiley & Sons, 1966. Chapters 6 through 11 give detailed information on sources and collection of water for domestic supply.

- Water Supply Engineering Design, M.A. Al-Layla, et al, Ann Arbor Science Publishers, Inc., 1977. Chapter 3 discusses various sources of water; Chapter 4, the collection of water from these sources; and Chapter 5, the distribution of water from source to impoundment and treatment.

- "North Marin's Little Compendium of Water Saving Ideas," John O. Nelson, March 1977, N. Marin Co. Water District., Novato, CA 94947.

SECTION 8

TREATMENT

Some of the most important questions concerning the treatment required to meet State and EPA quality standards are:

1. Why is water treatment required? (See Appendix F).

2. What are the objectives of water treatment? (See page 8-1, Appendix A, and Appendix C)

3. If an MCL is exceeded, how are excess concentrations removed? (See pages 8-1 and 8-2)

4. How are treatment processes selected? (See page 8-2)

5. What disinfectant should be used? (See pages 8-2 to 8-5)

6. What are the most effective general treatment methods for removal of various contaminants? (See page 8-7)

7. How reliable should water treatment processes be? (See pages 8-10 and 8-11)

Treatment is a critical aspect of public water supply. Inadequate treatment has been directly linked to several epidemics and suspected in many others. As an example, a chlorination failure led to a Salmonella outbreak in Riverside, California, in 1965. Over 16,000 illnesses were reported, 70 people were hospitalized, and three deaths were linked to the consumption of inadequately treated water. The National Interim Primary Drinking Water Regulations (NIPDWR) have been adopted to ensure that health standards are maintained for potable water.

The water utility is responsible for providing a safe, aesthetically pleasing water. The treatment required depends on the source and characteristics of the raw water supply. Since the passage of the SDWA and adoption of the NIPDWR, this task has become more straightforward in that there are clear goals to be met. This section presents only basic treatment processes that, when properly applied, will produce an acceptable product. Removal of certain constituents may be difficult and require more complex treatment systems than those discussed herein. Furthermore, future changes in regulations may necessitate even further treatment. In most cases it is advisable to employ a consulting sanitary engineer who is expert and experienced in water purification to select the treatment processes needed under given conditions.

OBJECTIVES

The principal objective of potable water treatment is to provide a safe aesthetically appealing product for human consumption at reasonable cost. This requirement has been clearly defined by the establishment of maximum contaminant levels (MCL) for specific pollutants. These regulations, defined in the NIPDWR, must be met by all public water purveyors. Detailed discussion of the primary as well as the secondary regulations is contained in Section 5 of this guide.

The MCL's for the regulated pollutants are summarized in Appendices A and C. These criteria are based on potential public health effects of consuming unsafe water and on extensive experience with the technical feasibility of achieving the MCL's as described in Appendix F.

Utilities should also be aware of unregulated problems which are presently beyond the scope of the NIPDWR.

PROCESS SELECTION

Although the basic objective of providing a high quality product is common for all water utilities, the specific steps required to do this will be different for each system because no two raw waters are exactly of the same quality. The type of treatment provided depends primarily on the quality and variability of the source of supply. As a minimum for all waters, disinfection must be provided to remove biological contaminants. Surface waters generally require filtration for turbidity removal and disinfection as minimum treatment. Groundwaters may require various mineral removal processes in addition to disinfection, depending on the inorganic composition of the well water. Both surface and groundwaters may contain organic compounds which require attention in treatment. A tabular summary of various processes which are effective in removing pollutants when properly applied is given in Table 8-1.

To determine fully all seasonal treatment requirements, a detailed sanitary survey must be completed. The most economical treatment system to meet the quality requirements can then be developed. Efficient operation involves varying the treatment operations as necessary to accommodate changing raw water characteristics.

If a water contains excessive concentrations of a substance for which an MCL has been established, there are economical treatment methods available for reduction of the concentration to acceptable limits. Discussions of these methods are beyond the scope of this report, but they are already described in detail and rather completely in an EPA publication, No. 600/2-78-182, "Estimating Costs For Water Treatment As A Function of Size and Treatment Plant Efficiency", MERL Cincinnati, Ohio, August 1978, as well as in "Manual of Treatment Techniques For Meeting the NIPDWR," EPA-600/8-77-005, MERL, Cincinnati, Ohio, May 1977. The EPA manual on treatment techniques discusses removal of radionuclides, inorganics, and organic substances. Each substance for which there is an MCL is discussed.

Simple Disinfection

Simple disinfection is considered the minimum treatment required for any water supply. It is used to destroy or inactivate biological contaminants in the raw supply. It may be the only treatment required in cases where the source is of high, consistent quality, such as groundwater or snowmelt. Alternate disinfection methods involve the use of chlorine dioxide, ozone, or chlorine-ammonia treatment.

TABLE 8-1. MOST EFFECTIVE TREATMENT METHODS FOR CONTAMINANT REMOVAL

Contaminant	Most effective treatment methods
Arsenic:	As^{+5} - Ferric sulfate coagulation, pH 6-8; alum coagulation, pH 6-7; excess lime softening As^{+3} - Ferric sulfate coagulation, pH 6-8; alum coagulation, pH 6-7; excess lime softening NOTE: Oxidation required before treatment for As^{+3} Ion exchange with activated alumina or bone char adsorption
Barium:	Lime softening, pH 10-11; ion exchange softening
Cadmium:	Ferric sulfate coagulation, above pH 8; lime softening; excess lime softening
Chromium:	Cr^{+3} - Ferric sulfate coagulation, pH 6-9; alum coagulation, pH 7-9; excess lime softening Cr^{+6} - Ferrous sulfate coagulation, pH 7-9.5
Virus and Coliform Organisms:	Disinfection; coagulation, and filtration plus disinfection
Fluoride:	Ion exchange with activated alumina; lime softening
Lead:	Ferric sulfate coagulation, pH 6-9; alum coagulation, pH 6-9; lime softening; excess lime softening
Manganese & Iron:	Inorganic - Oxidation/Sedimentation/Filtration Organic - Oxidation, Alum-lime coagulation, pH 9-9.6
Mercury:	Inorganic - Ferric sulfate coagulation, pH 7-8 Organic - Granular activated carbon
Nitrate:	Ion exchange
Organic Contaminants:	Powdered activated carbon; granular activated carbon
Radium:	Lime softening
Selenium:	Se^{+4} - Ferric sulfate coagulation, pH 6-7; ion exchange; reverse osmosis Se^{+6} - Ion exchange; reverse osmosis
Silver:	Ferric sulfate coagulation, pH 7-9; alum coagulation, pH 6-8; lime softening; excess lime softening
Sodium:	Ion exchange; reverse osmosis
Sulfate:	Ion exchange; reverse osmosis
Turbidity:	Coagulation, settling, and filtration, or direct filtration
Taste & Odor:	Chlorine dioxide, breakpoint chlorination, powdered and granular activated carbon, chlorine-ammonia, copper sulfate
Color:	Coagulation, powdered and granular activated carbon, or pre-oxidation with ozone and filtration through GAC - sand media
Iron & Manganese:	Oxidation, coagulation, filtration, softening, ion exchange

Disinfection is most commonly achieved using chlorine in the gaseous form for large treatment facilities or in the form of a hypochlorite compound for small systems. Chlorine gas is a heavy, greenish yellow substance that has a very low solubility in water. It is generally transported in containers in a liquified state. It is a respiratory irritant, requiring extreme care in handling. Hypochlorite compounds may be either dry or liquid. Except for small plants, they are generally more expensive than chlorine gas; however, they do not present the same dangers in handling as does elemental chlorine.

The risks involved in using chlorine gas, particularly in and near large metropolitan areas, have forced the use of alternative chlorine sources in certain cases. Sodium hypochlorite most closely matches the disinfecting properties of elemental chlorine; however, it is not stable for long periods of time and is required in proportionally higher volumes. An alternative to frequent deliveries is to generate the compound at the site of application. Several electrolytic processes have been developed using sodium chloride to generate sodium hypochlorite on site. These are most cost-effective if there is a nearby source of saltwater or waste brine.

The effectiveness of chlorine as a disinfectant is influenced by several factors. The pH of the supply determines the form of chlorine in the water. Hypochlorous acid is predominant at low pH (6.5 or less) while hypochlorite ion predominates at high pH (8.5 or greater). Of the two, the acid is more effective as a disinfectant. Therefore, the ideal pH for disinfection with chlorine is less than or near neutral (pH = 7.0 or less).

Turbidity may interfere with disinfection by sheltering the pathogenic organisms. Process effectiveness is higher with less turbid waters. Other chemical compounds can also interfere with the disinfection process. Ammonia or other nitrogenous compounds react readily with chlorine to form chloramines. Although the various chloramine compounds are effective disinfectants, their reaction rate is not as rapid as the hypochlorous acid.

The three most important aspects of effective chlorination are supplying an adequate dosage, providing proper mixing, and providing sufficient contact time. A minimum residual should remain in the distribution system to prevent recontamination of the product. The biggest threat of recontamination in the system is cross connections. An adequate residual or the reapplication of a small amount of chlorine in the distribution system can greatly reduce the potential for delivery bacteriologically unsafe water. The hydraulics of the treatment facility must be such that thorough mixing and sufficient contact are provided to allow complete disinfection. Short-circuiting can result in inadequate or uneconomical disinfection.

Recent revelations regarding the production of potentially harmful by-product in some instances where pre-chlorination is used have caused concerned persons to take a closer look at the use of chlorine and at the possible use of alternative means for pre-oxidation and disinfection. One of the principal results of this closer look to date has been to reserve the use of chlorine for final disinfection of the purest quality water present in the plant, and to use other oxidants earlier in the water treatment process. This may be a means for reduction of chlorine by-products (notably the trihalomethanes). The recent regulatory activity of EPA regarding triholomethanes (THM) means that water utilities should look more closely at the disinfection processes and procedures which they employ. Ozone, chlorine dioxide, potassium permanganate, chlorine-ammonia, hydrogen peroxide, and other oxidants have been used. Not much is known about by-products from the use of these materials, but the production of chloro-organic compounds is reduced. Oxidants other than chlorine have successfully replaced chlorine in many applications for color removal, taste and odor control, algae control, and as an aid to coagulation of organic matter.

Despite its replacement in many pre-treatment applications, chlorine is still relied upon as the principal means for final disinfection. Ozone, chlorine dioxide, and other chemicals have found limited use as the final disinfectant.

Removal of Coliform Organisms. The EPA "Manual of Treatment Techniques For Meeting The IPDWR" (hereinafter - in this section - referred to as the EPA Treatment Manual) discusses this subject under the topics of MCL's, turbidity, disinfection byproducts, chlorination, ozone, chlorine dioxide and costs on pages 42-52.

Removal of Inorganic Contaminants. The EPA Treatment Manual presents methods for removal of arsenic, larium, cadmium, chromium, fluoride, lead, mercury, nitrate, selenium, and silver both in existing and new treatment facilities on pages 7-36.

Turbidity Removal

See the EPA Treatment Manual pages 44-52.

Low turbidity is a good measure of the safety of water. Low turbidity allows the use of reduced doses of disinfectant, and provides a greater degree of protection. Under the NIPDWR, the turbidity of supplies from surface waters must be measured on a daily basis. With the limitation being 1 TU on a monthly average, virtually all surface supplies will require filtration for turbidity removal. As well as meeting the federal quality requirement, turbidity removal may be necessary to provide adequate disinfection, to maintain a chlorine residual, and to allow accurate bacteriological testing.

The common methods for removing turbidity are direct filtration, or chemical coagulation, flocculation, and sedimentation, followed by filtration. The first method is used for raw water with a fairly low initial turbidity (generally less than 25 JTU), while the second is effective on sources with a high or variable turbidity. The basic process trains for these two systems are shown on Figures 8-2 and 8-3 . They also include disinfection as described previously.

Filtration is the process by which suspended and colloidal particles are removed from water by passing it through a bed of granular material. As the water passes through the medium, the fine particles are trapped in the spaces between grains or are adsorbed on the surface of the filter media. Chemical aids are often used to enhance the performance of filtration. Coagulants such as alum or polymers promote flocculation of the suspended materials and adsorption on the filter grains.

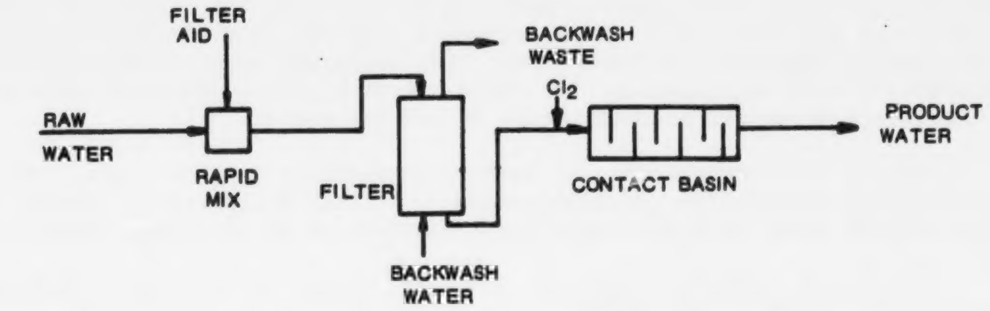
FILTER AID
RAW WATER
RAPID MIX
FILTER
BACKWASH WASTE
BACKWASH WATER
Cl2
CONTACT BASIN
PRODUCT WATER

Figure 8-1. . Schematic diagram of direct filtration for turbidity removal and disinfection.

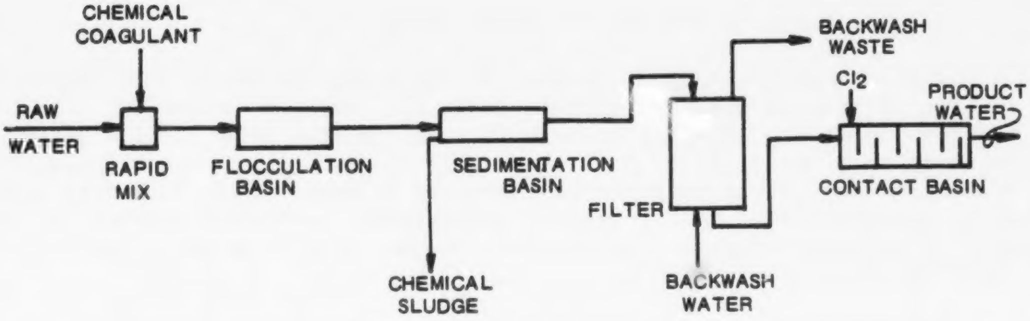
CHEMICAL COAGULANT
RAW WATER
RAPID MIX
FLOCCULATION BASIN
SEDIMENTATION BASIN
CHEMICAL SLUDGE
FILTER
BACKWASH WASTE
BACKWASH WATER
Cl2
CONTACT BASIN
PRODUCT WATER

Figure 8-2. Schematic diagram of conventional treatment for turbidity removal and disinfection.

Granular media filters can be classified by a number of features, including type and arrangement of media, direction of flow, flow rate, or pressure or gravity operation. Each characteristic has advantages and disadvantages which must be assessed for the particular application.

- Filter media may be a single, uniform material or layers of different size and specific gravity of materials. Sand was among the first media used for filtration. Dual media filters have a layer of anthracite coal of larger effective size that is supported by a layer of sand. This design greatly increases the effective depth of the filtration over that provided by a simple sand filter. Mixed media filters typically contain three types of media graded from coarse to fine, with coal on the top, sand in the middle, and crushed garnet on the bottom. This arrangement can offer improved performance, as measured by length of filter runs and the final product quality, for many applications.

- Most potable water filters are downflow, and backwashing is upflow from the bottom of the filter which drives the trapped particles to the surface of the filter through the layers of media. In the U.S. water backwash is usually supplemented by hydraulic surface scour. In Europe air-water backwash is commonly preferred.

- Filters are generally classified as either high rate or low rate. Rapid sand filters operate in a range of 2 to 4 gpm/sq ft (gallons per minute per square foot) and require frequent backwashing. (Mixed or dual media filters may be run at rates above 5 gpm/sq ft). Slow sand filters are operated at a maximum of about 0.10 gpm/sq ft of bed area; therefore, they require much more space than rapid filters.

- Filters can be designed to operate under pressure or by gravity flow. Most filters for public water supplies are open gravity units. Some states permit the use of pressure filters for treatment (usually softening or iron or manganese removal) of high quality well waters. Because pressure filters are closed, it is not possible to observe the condition of the media, nor is it possible to visually monitor the loss of media during backwashing. Residual pressure from the pressure filtration process can be utilized for water distribution. Gravity filters are constructed with open tops, allowing observation of the media during operation and backwashing. Gravity filters are much more suitable for surface waters.

The three most common types of filters used in water treatment are rapid gravity, rapid pressure, and slow gravity. In general, mixed or dual media filters can tolerate higher input turbidities (up to 50 JTU) whereas the single sand media filters must have lower turbidities (less than 10 JTU) for efficient operation because of their lower effective bed depth.

Often coagulation, flocculation, and sedimentation will be required prior to filtration. These processes can remove color as well as turbidity when properly applied.

- Coagulation is a very rapid process which occurs when a coagulating chemical, generally an aluminum or iron salt, is added to the water. The colloidal particles, which cause the turbidity, carry electrical charges that tend to hold them apart. The addition of the coagulant reduces these charges so the small particles will agglomerate (flocculation) forming particles large enough to settle by gravity. Coagulation can be used immediately preceding filtration for low turbidity waters, but is often followed by flocculation and settling to remove some solids and prevent excessively short filter runs.

- Flocculation is a much slower process in which aggregation occurs during prolonged, gentle mixing to create large, readily settleable particles. As opposed to the relatively short contact time in rapid mixing (20 sec to 2 min), flocculation is best if a slow mixing or gentle agitation is carried out for 15 to 45 minutes.

- Sedimentation, or clarification, allows the flocculant solids formed by chemical addition to settle out of the water by gravity. The accumulated chemical sludge is removed from the bottom of the clarifier periodically for subsequent disposal. Recently, high rate settling has been accomplished by the development of tube settling devices which employ principles of shallow depth sedimentation to reduce the surface area requirement of settling basins.

Numerous factors affect the performance of chemical processing. These include:

- The pH of the raw water - there is an optimum range for each source

- The dissolved solids content - this influences the optimum coagulant dose, the flocculation time, and the residual coagulant concentration in the effluent, and can shift the optimum pH range

- The nature of the turbidity - amount of clay and other mineral particles

- The type of coagulant - alum is the most common, sometimes oxidants or polymers are added to enhance floc formation

One way to determine optimum dosages for chemical clarification is to run laboratory jar tests. Properly done these results can provide basic design and operating parameters for a specific supply. In some cases Zeta potential or colloidal titration may be used. A better way to control chemical coagulation is by installation of a pilot filter or coagulant control center designed for the purpose (see page 109 in the first reference at the end of this section).

Chemical clarification followed by filtration has been shown to reduce the concentrations of turbidity, color, certain heavy metals, pesticides, inorganics, radionuclides, and bacterial contaminants and to aid disinfection processes.

Removal of Organic Contaminants. This subject is discussed on pages 53-61 of the EPA Treatment Manual, under the topics as follows: occurrence of pesticides in drinking water; Endrin; Lindane; Toxaphene; 2, 4-D; 2, 4, 5-TP (Silvex); Methoxychlor; cost; and adsorption with PAC and GAC.

Removal of Radioactive Contaminants. The EPA Treatment Manual presents techniques for this purpose on pages 62-72. Topics include: alpha emitters; radium (by ion exchange, lime or lime-soda softening, and reverse osmosis); disposal of treatment water; costs; and manmade radionuclides, or Beta and Photon emitters.

WATER TREATMENT FOR CORROSION CONTROL

Corrosion control can reduce the rate of deterioration of pipelines and the loss of carrying capacity. It also can prevent adverse health effects which might arise from the solution of cadmium, lead, copper, or zinc, or the suspension of asbestos from the interior of pipes by aggressive water followed by the drinking of the contaminated water. There is no generally accepted index of corrosion, but corrosion control is widely practiced.

Chemical control of corrosion is a supplement to protective construction measures against corrosion which include use of copper or copper alloy for service line piping, coating pipes with zinc (steel pipe) or coal tar (cast iron pipe), lining with cement, and in-place coating after main cleaning. Chemical control of corrosion requires constant surveillance. Low calcium, alkalinity, and pH favor corrosion. It is possible to maintain proper concentrations and vital interrelationships among these factors by control of treatment in filter plants, or by the addition of chemicals for pH control to water in storage or in the distribution system. Also, polyphosphates, sodium silicate, bimetallic phosphates, and other chemical additives may be used effectively in some situations.

CHEMICAL HANDLING

Chemical handling can be a fairly simple, safe task if the equipment is well designed and properly maintained. The basic factors influencing the operability of chemical handling equipment area as follows:

- Application - the point of application should assure maximum treatment efficiency and flexibility, and ease in maintenance.
- Feed equipment - the feed equipment should be adequately sized for operation at maximum flow; conveniently located near point(s) of application; readily accessible for servicing, repairs, and observation; and manually or automatically controlled with feed rate proportional to flow.
- Feed lines - feed lines should be as short as possible to minimize clogging; constructed of durable, corrosion-resistant material; easily accessible throughout entire length; protected against freezing; and readily cleanable.

- Storage - storage capacity should be for at least thirty days and arranged so that oldest chemicals are used first, in a convenient location, and clearly marked; chemicals should be stored in original shipping containers if possible; safety practices should be outlined for acidic, caustic, toxic, explosive, and combustible chemicals.

- Safety - safety while handling chemicals cannot be overstressed; operators should be trained and familiar with all procedures for storing, mixing, and feeding chemicals; work areas should be well ventilated; equipment for handling chemicals (gloves, etc.) and for emergencies (air packs, fire extinguishers, respirators, eye washes, etc.) should be clearly marked and readily available for use; spills should be cleaned up immediately and general good housekeeping should be practiced.

Specific details on handling each of the chemicals used in water treatment can be found in Water Quality and Treatment; A Handbook of Public Water Supplies, AWWA, 1971, Chapter 17, and in Water Purification Control, Hopkins and Bean, Williams and Wilkins Co., Baltimore, 1966.

OPERATION AND CONTROL

The importance of proper plant operation cannot be overstressed. Regardless of how well a treatment facility is planned and designed, it serves little purpose if not properly operated and managed. The basic processes commonly used in water treatment are few, and monitoring of performance is quite easy. If done correctly and regularly, operation will be efficient and economical.

Chlorine dosage can be automatically adjusted by plant flow and chlorine residual. Simple, reliable equipment is available to automatically control chlorine feed, and it should be used. Other chemical feeds can also be controlled by readings from continuous monitors. Continuous turbidity monitoring of filter effluent can be used to control filter operations.

The specific details of operating each treatment process should be provided by the equipment manufacturers and the design consultant. A comprehensive Operations and Maintenance manual, as described in Section 9 of this manual, should contain all of the pertinent information required to operate and maintain water treatment facilities.

RELIABILITY

The reliability provided in water systems is generally greater than that in sewerage systems and about equal to that of electric power systems. Even greater reliability could be obtained at higher costs. The reliability of water supply is an important consideration in system design and operation. Certain emergencies that may disrupt water service are uncontrollable, but many can be avoided.

Since water treatment is a continuous activity, routine maintenance and repairs also have the potential for disrupting service. To minimize the inconvenience of planned or unplanned interruptions in service, the following basic elements should be considered.

- Plant capacity should be sufficient to meet customer demands.
- At least two of each unit should be provided whenever possible, even at very small facilities; one can be operated while the other is being serviced.
- Standby capacity should be sufficient to ensure operation with the largest unit out of service.
- Spare parts for common repairs and hard to get parts should be kept on hand.
- Chemical supplies should be sufficient for at least 30 days of plant operations.
- Regular servicing of all mechanical equipment will minimize emergency shut-downs.
- At least two independent sources of power should serve the treatment plant.
- The operating staff should be familiar with emergency procedures.
- Water storage facilities can improve the reliability of the water supply, particularly during peak demand periods.

REFERENCES

- New Concepts in Water Purification, R.L. Culp, and G.L. Culp, Van Nostrand Reinhold Company, New York, 1974. Newly developed and improved processes for water treatment including filtration, sedimentation, and disinfection; design criteria, operational control, and typical costs are included.
- "Water Treatment Plant Design," AWWA, 1971. Gives detailed design information for common water treatment processes.
- "State of the Art of Small Water Treatment Systems," U.S. EPA, August, 1977. Unit processes for meeting primary and secondary drinking water requirements are discussed in terms of design, performance, controls, operation, and applicability; examples of upgrading existing facilities are also given.
- Water Quality and Treatment; A Handbook of Public Water Supplies, 3rd Ed., AWWA, 1971. Common unit processes for water treatment are described in detail. Chapter 17 describes the characteristics, use, handling, etc., of all chemicals used in water treatment.
- "Technical Guidelines for Public Water Systems," U.S. EPA, June, 1975, NTIS #PB 255 217, Chapter 3 details design criteria and application of unit processes used in water treatment. Chapter 4 covers chemical handling, application, and safety practices.

- "Estimating Costs for Water Treatment as Function of Size and Treatment Plant Efficiency," U.S. EPA, August 1978, EPA 600/2-78-182. Chapter II deals with treatment methods available to meet the NIPDWR.
- "Manual of Treatment Techniques for Meeting the IPDWR", EPA-600/8-77-005, MERL, Cincinnati, Ohio, May 1977.
- "Water Purification Control", Hopkins and Bean, 1966, Kreiger Publishing Company, Huntington, N.Y.
- "Handbook of Chlorination", G.C. White, Van Nostrand Reinhold Co., N.Y.

SECTION 9

WATER TREATMENT WASTES

1. For many years basin sludge and filter backwash water from water treatment plants were returned to streams from whence they came - why do they now require special handling prior to discharge? (See page 9-2)

2. What are the presently available alternatives for disposal of water treatment plant wastes? (See page 9-3)

3. Are there opportunities to recycle treatment chemicals and wastewater within filter plants? (See page 9-2)

4. What methods are available for sludge dewatering? (See page 9-3 and Table 9-1)

It has only been within the past few years that the wastes produced during water treatment have received significant attention. In the 1950's, over 90 percent of basin sludge and other solid wastes and 80 percent of filter backwash from water treatment were discharged to surface waters. Water pollution control laws (notably Water Pollution Control Act as amended in 1979) instituted in the early 1970's prohibited such practices. Sludge from water treatment plants is now considered an industrial waste and is subject to the same regulations regarding treatment and disposal. Arsenic, fluoride, and radiological wastes, when present in water treatment sludges, are considered as hazardous materials by EPA.

Since waste disposal represents a newly introduced expense for most water utilities, all efforts to reduce costs should be considered. Water conservation and increasing operational efficiency are straight-forward means for reducing the quantity of wastes produced. This may warrant process modification for existing facilities. For example, substituting polyelectrolytes for part or all of the alum used in coagulation can substantially reduce the amount of chemical sludge produced, but at higher chemical cost.

Various aspects of water treatment waste disposal are discussed in the following paragraphs. The methods actually employed by different plants will vary considerably, depending on the size and location of the facility, treatment processes employed, climatic conditions, and local and state rules governing disposal practices.

SOURCES

The principal sources of waste from water treatment are the natural solids removed from raw water and the precipitates formed by chemical addition. It is difficult to typify the nature of wastes generated during production since the characteristics of raw water vary greatly.

Alum is the most common chemical coagulant used for removing solids from water; an alternative is ferric chloride. Sludges are mainly metal hydroxides with entrained organic and inorganic particulate matter. Most alum sludges are particularly difficult to dewater due to their gelatinous nature. The specific characteristics of the sludge depend on the raw water being treated. Sludge volume usually represents about one percent of the raw water treated and liquid sludge typically has a solids content of 0.5 to 2.0 percent.

The solids removed during granular filtration are wasted in filter backwash water. The components in the backwash water are highly dependent on the raw water characteristics and on any pre-filtration processing. They may include polymers, metal oxides, carbonates and silicates, organics, and carbon. The volume of filter backwash is usually 1 to 5 percent of the volume of raw water treated. It has a low solids content, ranging from 0.01 to 0.1 percent, and may be recycled through the treatment process.

SLUDGE DISPOSAL METHODS

Some sludge handling methods are concerned only with direct disposal, others provide for recovery and reuse of treatment chemicals and salvage and reprocessing of wastewater. Some of the alternates are: discharge to sanitary sewers (where permitted); disposal in lagoons; use of sand drying beds; dewatering by vacuum filtration, centrifugation, filter pressing, lime sludge pelletization, heat treatment, or freezing; alum recovery by acid or alkaline methods; magnesium carbonate recovery; and lime recalcining and reuse.

RECLAMATION AND REUSE

The increasing cost of chemicals and the new regulations regarding disposal have directed attention toward reclaiming the chemicals used in water treatment. Lime recovery has been practiced at many larger treatment facilities employing softening, but alum recovery has not been found to be economical except in a few cases. Recently, there has been progress in improving the methods used to recover alum from the chemical coagulation process.

Alum Recovery

Alum can be recovered from coagulation sludge using an acid processing technique. Thickened sludge is treated with acid (commonly sulfuric acid) to dissolve the aluminum salts. The residual (waste) solids are then removed by gravity. Although the potential benefits of alum recovery may be significant in terms of production and process energy conservation and chemical costs, there are some potential drawbacks associated with the practice. The accumulation of heavy metals and other impurities has been a deterrent to the use of alum recovery. Ongoing studies with the acid process and with other alum recovery methods like liquid ion exchange may provide useful information for planning such systems.

Alternative Reuses

Two principal alternatives to in-plant chemical reuse have been proposed. One is to use either alum or lime sludge as a soil conditioner. Both enhance the cohesiveness of the soil. The lime sludge can be used to neutralize acidic soils.

Another alternative for reusing chemical sludges from water purification is in wastewater treatment. Water treatment sludges are often beneficial in waste water treatment, but this depends on local circumstances which must be investigated.

SLUDGE DEWATERING

Dewatering sludge reduces the volume of sludge to be disposed. Sludges concentrated to at least 20 percent solids are reduced in volume by 75 percent and are much more easily handled by mechanical equipment and do not present the same disposal problems of thinner sludges (less than 5 percent). Dewatering can be achieved by physical or mechanical methods. Process selection depends on the source and quantity of sludge, its dewatering characteristics, the availability of land near the treatment plant, and the method of ultimate disposal or reuse.

Sand beds and lagoons are methods typically used at smaller facilities which have land available. They are dependent on climatic conditions for proper performance. If landfill disposal is practiced, additional dewatering may be necessary to achieve a manageable solids concentration. Common mechanical methods for dewatering include vacuum filtration, centrifugation, and pressure filtration. These achieve higher solids concentrations for chemical sludges, but may require preconditioning for optimum performance. Table 9-1 summarizes the alternatives for water treatment sludge dewatering.

LANDFILL DISPOSAL

The most common method of ultimate disposal of water treatment sludge is landfill. For small systems in rural areas, lagooning may be used; in this case, a lagoon is simply filled, stabilized, and abandoned.

Landfilling operations are favored. They must be controlled to protect groundwaters and surface waters from leachate and runoff contamination. The variability of sludge characteristics can present problems in planning and operating a landfill for such sludge. In many states, water treatment sludge is considered an industrial waste, which may limit the landfill disposal options. As previously mentioned, EPA classifies arsenic, fluoride, and radiological wastes in water treatment plant sludge as hazardous materials requiring special disposal.

Sludge dewatering is almost always essential prior to landfill disposal since it reduces the volume and the potential for runoff and leachate contamination.

The planning and operation of a sludge landfill depends on several basic factors. These should be considered in the overall evaluation and economic analysis of the project.

- Location of water treatment plant
- Type and quantity sludge to be disposed of
- Proximity to existing landfills; available capacity for chemical sludge disposed

TABLE 9 -1. ALTERNATIVE SLUDGE DEWATERING METHODS

Method	Application	Comments
Physical		
Sand Beds	Chemical coagulation sludges may dewater to 20 percent solids	Need large land area and long detention times; weather-dependent; decant water and under-drainage are discharged sanitary sewer, surface water, or returned to plant; high labor demand for cleaning beds; applicable to small systems
Lagoons	Chemical coagulation dewater to 10 percent solids	Common method for small systems; takes advantage of natural freezing and evaporation to aid in dewatering; can be used for temporary storage; low operating costs; can promote insect breeding; may need further dewatering before use in landfill
Mechanical		
Vacuum Filtration	Limited application in water treatment	Precoating filter with diatomaceous earth is necessary for vacuum filter dewatering of alum sludge; high costs, both capital and O&M
Centrifugation	Conditioned alum sludge dewatered to 15 to 20 percent solids	May require polymer addition for effective operation.
Filter Presses	Conditioned alum sludge dewatered to 30 pecent solids	Alum sludge must sludge dewatered be conditioned with lime before dewatering; filtrate disposal may be a problem since it has a high pH and may have a high heavy metal concentration; disadvantages include short life of filter cloth and need for manual control.

- Labor and energy requirements for landfill operation
- Alternatives to disposal at a landfill
- Local regulations

DISCHARGE TO SANITARY SEWERS

Under certain circumstances, discharge of chemical sludge to sanitary sewers may be an acceptable or beneficial means of disposal. In some cases, this practice merely represents transferring the solids handling from one plant to another; but for other communities, it may be the most economical solution to the overall solids disposal problem. Factors to be considered in discharging water treatment wastes to wastewater plants include:

- The hydraulic and solids capacity of the wastewater treatment plant and sewers

- The compatibility of water treatment sludge with the wastewater treatment process and the effect on effluent quality

- The hydraulic capacity of the sewers from the water plant to the wastewater treatment plant; if the velocity is insufficient, solids deposition can clog or greatly reduce the hydraulic capacity of the sewers

- Classification of water treatment wastes; industrial pretreatment standards may be imposed

REFERENCES

- "Water Treatment Plant Sludges - An Update of the State of the Art: Parts 1 and 2," Commitee Report, JAWWA, September and October, 1978. Part 1 details the current regulatory requirements, sludge production and characteristics, and minimizing production of water treatment wastes; part 2 outlines processing methods, including nonmechanical and mechanical methods of dewatering sludge and methods of ultimate disposal.

- "Alternate Processes for Treatment of Water Plant Wastes," S.L. Bishop, JAWWA, September, 1978. Discusses alternate methods of handling wastes produced in water treatment, including recently developed processes for alum sludge processing.

- Water Quality and Treatment; A Handbook of Public Water Supplies, 3rd Ed., AWWA, 1971, Chapter 19. Presents sources quantities, characteristics, and processing of water treatment residues; includes environmental and legal aspects.

- "State of the Art of Small Water Treatment Systems," U.S. EPA, August, 1977, pp. IV-61-70. Presents sources, quantities, and characteristics of wastes produced in water treatment; various treatment methods; and ultimate disposal practices.

- "Manual of Treatment Techniques For Meeting The IPDWR," U.S. EPA 600/8-77-005, 26 W. St. Clair Street, Cincinnati, Ohio 45268, May 1977.

- "New Concepts In Water Purification," Chapter 5, Disposal of Sludges, G.L. Culp and R.L. Culp, Van Nostrand Reinhold, New York, 1974.

- "Beneficial Disposal of Water Purification Plant Sludges In Wastewater Treatment," John O. Nelson, Chas. A. Joseph, R.L. Culp, EPA Report S-803336-01-0, Cincinnati, 1978.

SECTION 10

DISTRIBUTION

Water distribution systems should be sized to handle variable customer demands and requisite fire flows. Quality standards must be met throughout the system. Good circulation of water should be provided and cross connections prevented.

Various general aspects of water distribution are discussed in this section. Many requirements are system-specific.

Some common questions concerning the distribution of water are:

1. Why is it important from a public health standpoint to consider fire demands on a water distribution system? (See pages 10-1 and 10-2)
2. What range of water pressures provides acceptable water service? (See page 10-2)
3. What functions are served by storage of water on distribution systems? (See page 10-3)
4. Why is a program of cross-connection control essential to safe water? (See pages 10-4 and 10-5)

SERVICE

Many water utilities provide service to more than one type of customer. Potable water supplied for domestic and commercial uses must meet the quality criteria established by the SDWA. In certain cases, industrial process water may have more stringent limitations for certain constituents, whether or not they are met by the water purveyor or through supplemental treatment by the industrial user will depend on individual circumstances.

The overall demands on the system can be estimated from total flow records and from the demands of similar communities. Careful distribution analysis is important to ensure that localized flow demands are met. For example, a densely populated business area may have exceptionally high daytime demands and low evening and weekend needs. On the other hand, a large industry operating 24 hours a day will require a steady supply on a continuous basis. Such service factors, as well as seasonal source and demand variations, will influence the overall planning and operation of a system.

FIRE PROTECTION

Providing adequate fire protection is important to public safety and to minimize cost of fire insurance. It is also important because large withdrawals of water from mains which are too small for fire fighting often produce low pressures or negative pressures in water mains - a health hazard due to back syphonage. Communities are rated by the Insurance Service Offices (ISO) or other fire underwriters (see the local insurance agents) according to the level of fire protection they provide. A system of deficiency points, assigned in an evaluation of the water supply, the fire department, fire service communications, and fire safety control, determines the relative class of the area and the associated insurance rates.

The evaluation of the water supply system for fire protection afforded is based on many factors including, but not limited to:

- Deliverable flow rates
- Adequacy and reliability (duplication of vital facilities)
- Storage facilities
- Reliability of power supply (standby for electric service)
- Multiplicity of water supply to the service area
- Sources of emergency supply
- Distribution system characteristics such as layout, minimum pipeline size (recommended practice is six inches), minimum residual pressure (recommended minimum pressure = 20 psi), location of valves and hydrants, etc.
- Gravity service and pumping facilities
- Hydrant and valve location records

The basic fire flow rate is determined by the representative fire potential of most large properties in the district. Individual rates are calculated using a formula which includes the type of building materials, the total floor area, and the number of stories or height of the building. Once the basic rate has been calculated, reductions and increases are made for factors such as sprinkler systems, degree of hazard, proximity to other buildings, etc.

The minimum fire flow for any single building, including all reductions is 500 gpm, while the maximum rate is 12,000 gpm. The basic fire flow rate is added to the average consumption on the day of maximum use in order to determine the minimum system capacity. Depending on the system water use characteristics, this value may be exceeded by peak hourly consumption during the maximum month of use.

The fire protection provided by a utility should be periodically assessed to be sure it is adequate. When substantial improvements to the system are made, a reassessment by ISO may be warranted. It must be remembered, however, that factors other than water supply contribute to the fire protection rating and the associated fire insurance rates.

Three publications of the Insurance Services Office (160 Water Street; New York, N.Y.; 10038) should be consulted for additional information regarding fire protection.

- "Guide for Determination of Required Fire Flow"
- "Grading Schedule for Municipal Fire Protection"
- "Commentary on the Grading Schedule for Municipal Fire Protection"

Also see local insurance agents regarding rating system they use.

DISTRIBUTION MAINS

The distribution system should be capable of providing reliable water delivery with a minimum of service interruptions. The utility may have a formidable job in maintaining service if all or parts of the system are old or if several independent systems have been joined together to form a single system.

Considerations in the design of new systems or in the upgrading of existing systems include:

- Locating mains to provide service to all present customers so that extensions can easily be made for future expansions
- Maintaining adequate pressures in the system (minimum 20 psi at delivery point; normal static pressure of 60 to 75 psi; maximum 100 psi)
- Maintaining adequate flow in all points in the system (minimum pipe diameter of six inches)
- Ease of operation and maintenance; minimizing potential service and traffic disruptions during emergency repairs and routine maintenance
- Following a consistent pattern for locating valves, hydrants, and other connections
- Minimizing the potential for cross connections with sewer lines, drains, and other sources of contaminants
- Loop lines which connect dead ends and provide water circulation are preferred over dead-end lines in system extremities

The materials used for the distribution system should be selected to suit the local conditions and service applications. Pipelines may be ductile iron, steel, reinforced concrete, and plastic meeting AWWA standards. All plastics are not universally accepted since some may contain leachable toxic materials. A consideration in selecting pipe materials is corrosion control. Corrosion can be caused by reactions between the water and pipe material as well as by the soil and the pipe material. In some cases, it is most economical to line and/or coat the pipe with a non-toxic, non-reactive material to prevent corrosion rather than substitute a different material.

Valves are included in pipe systems to isolate sections of the system and to allow lines to be drained for repairs. Valves should be located to provide the maximum flexibility in isolating lines while minimizing the disruption in service. The actual location in the system depends on the size and type of line. The following are general guidelines for the location of valves. Specific system requirement may dictate the exact location of some valves. (See Table10-1). Records of valve locations should be maintained.

Fire hydrants should be located throughout the system but only on lines capable of delivering flows of at least 500 gpm. To ensure the adequacy of hydrant locations, the ISO guidelines should be consulted.

TABLE 10-1. GUIDELINES FOR LOCATING DISTRIBUTION SYSTEM VALES

Application	Location
Transmission Lines	According to operational requirements
Feeder Mains	Every 3,000 ft for 16-in. or smaller lines; 4,000 ft for 20-in. lines
Service Mains	Adequate to shutdown with minimum service interruption
Residential Service	Every 1,000 ft on 6- and 8-in. lines; 2,000 ft for 10- and 12-in. lines
Creek, Railroad, or Highway Crossings	Each side of crossing
Hydrant Branch	Control valve on each branch

STORAGE

Finished water storage can be designed to serve several purposes. Storage can be used to meet variations in production and system demands, to provide fire protection, and to serve in the event of a system failure.

Storage makes it possible to process water at times when the demands are low, for later use. This can reduce the required capacity of both treatment and transport facilities. Storage facilities can be located near the high demand areas and in high places to make maximum use of patterns and topographical features of the service area. Properly located storage facilities can reduce operating costs by minimizing pumping requirements, particularly during peak demand times for water. With the development of energy shortages, consideration has been given to doing as much water pumping as possible during off-peak demand periods for electrical power by use of storage.

Storage for fire protection depends on certain system features such as the minimum fire flow demands, the amount of system redundancy, the standby power system, and the emergency operation program.

There are three basic types of storage structures - elevated, ground level at an elevation which provides gravity flow into the system, and ground level requiring repumping. Finished water storage should be covered to protect against contamination. A certain amount of water should be drawn from storage on a daily basis to provide the circulation and mixing needed to minimize tastes and odors. Large reservoirs with long holding times should include provisions for water circulation.

CROSS CONNECTION CONTROL

Cross connections are any direct or indirect physical connection with the potential for contaminating a potable supply with non-potable water or liquid. Cross connections cannot be allowed even on a temporary basis.

Cross connections fall into two general categories, pumping hazards and back syphonage. Backflow hazards from pumping are caused when the contaminating private water source is pumped to a higher pressure than the public supply. To protect against such hazards, the basic cause should be eliminated by providing the public supply to the service through an air gap system or backflow prevention device. Another pumping hazard is the creation of low (below 20 psi) pressure on the suction side of booster pumps. This can be avoided by means of a low pressure pump cut-off device installed in the suction line. Back syphonage occurs when negative pressure develops in the system due to dewatering of a pipeline or from excessive demand on the main. It is often a problem in tall buildings with inadequate water systems.

A comprehensive cross connection control program is essential in providing high quality water and protecting public health. Several general factors should be considered in minimizing the dangers presented by cross connections.

- Locate water lines as far from sewers as possible. If they must be near each other, have water lines above sewers (never in the same trench to eliminate possible contamination of the water) and operating at higher pressures.

- Prevent negative pressures by minimizing planned shutdowns, maintaining adequate supplies, providing adequate capacity in lines, and using booster pumps to serve high areas in the system.

- Assure an adequate inspection program for potential cross connections on customer premises.

- Require adequate backflow prevention devices such as air gap systems, double-check valve assemblies, reduced-pressure-principle backflow preventers, etc. and adequate maintenance of such devices.

Cross connection control must be practiced and the regulations enforced if the quality of the system is to be maintained and the public health protected.

Check with the State Health Officer to see if there is a State cross connection control program, and what State requirements are.

REFERENCES

- "Technical Guidelines for Public Water Systems," U.S. EPA, June 1975, NTIS #PB 255 217, Chapters 6 and 7. Chapter 6 discusses the storage of finished water, including the type, location, capacity, and protection of storage basins. Chapter 7 summarizes distribution system requirements and standards; includes design criteria, materials and installation methods, valve locations, protection of system, etc.; cross connection prevention and correction discussed.

- "Water Distribution Training Course," AWWA Manual M8. Covers all aspects of distribution systems including planning, design, installation, operation and maintenance of pumps, storage, and pipelies.

- "Guide for Determination of Required Fire Flow," "Grading Schedule for Municipal Fire Protection," and "Commentary on the Grading Schedule for Municipal Fire Protection," Insurance Services Office, 160 Water Street, New York, N.Y. 10038. Outlines fire flow requirements and procedures for evaluating system for insurance purposes.

- "Cross Connection Control Manual," U.S. EPA, 1973.

- "Cross Connections and Backflow Prevention," by Gustave J. Angele, Sr., AWWA Manual.

SECTION 11

OPERATION AND MAINTENANCE

A sound operation and maintenance program is an important key to running a successful water utility. Regardless of how well a system is designed, a high quality product cannot be delivered on a regular basis if the system is not operated correctly. Proper maintenance can also extend the useful life of a facility. The topics discussed in this section cover the basic areas to be considered in planning or revising an O&M program. Some pertinent questions include:

1. How should operations and maintenance be organized? (See page 11-1)
2. What should be included in an O&M (Operations and Maintenance) manual? (See pages 11-2 and 11-3)
3. What routine basic operations are involved in water system operations? (See page 11-3)
4. What role does maintenance play in reliability of water service? (See pages 11-3 and 11-4)
5. What tools, equipment, and supplies are essential to good O&M programs? (See page 11-4)
6. What records of O&M are useful? (See page 4-3)

ORGANIZATION AND PERSONNEL

The organization and training of the staff is important to proper operations and effective maintenance. Supervisors should be qualified for the jobs they hold and must be given the authority to carry out their responsibilities. Many states have certification programs which serve as an effective way of evaluating an individual's qualifications. The staff should be assigned to jobs which suit their knowledge, skills, and experience.

Following certain basic management practices will minimize the organizational problems encountered in operating a water utility.

- There should be a clearly defined, easy to follow operational program. Routine jobs should be scheduled and the schedules followed. Periodic tasks should be integrated into the regular operations program.
- All personnel should have specific job assignments. Reporting procedures should be such that duties and tasks are self-monitoring. This minimizes the amount of direct supervision and transfers more responsibility to individual staff members.
- For larger facilities, operations and maintenance may be carried out by two separate groups of people. Distinct channels for communication should be established among all staff groups, but particularly between the operations and maintenance staffs.

- Regular, informal facility inspections and reviews of the organizational structure will give an indication of the effectiveness of the management program. The efficiency of plant operations demonstrate whether or not the personnel are carrying out their assigned jobs. The attitudes of the staff members are the main indicator that they are happy with their jobs and that the organization is functioning well.

More detailed information on personnel is given in Section 3.

PROCEDURES AND EQUIPMENT

The requirements of an effective O&M program vary with the system size, age, and specific facilities. As a minimum, most water utilities operate supply, treatment, and distribution facilities. In some systems, the treatment process will demand the most attention. On the other hand, an old distribution system may need extensive servicing and frequent repairs if it is to remain operational.

The basic elements of a good O&M program are discussed in the following paragraphs.

O&M Manual

Preparing and maintaining a comprehensive, up-to-date operation and maintenance manual is important for effective and efficient system performance. A minimum manual would consist of a loose-leaf binder including the manufacturers' O&M instructions for each piece of equipment. More comprehensive information, again bound in a manner that lends itself to easy revision, is preferable. It should include the information collected by the consulting engineer, material supplies, and contractor during project construction. The O&M manual should be indexed by process, function, or facilities, and should be stored in a convenient, accessible location. Useful information contained in the O&M manual may include, but not necessarily be limited to the following:

- Detailed schematic diagrams of pipelines, valves, and controls
- Precise, detailed instructions on how various pieces of equipment are to be operated, maintained, and repaired
- Routine maintenance schedules (including grounds maintenance and routine "housekeeping")
- Lubrication charts including lists of recommended lubricants
- Sample recording and reporting forms, with completed examples
- Emergency and safety procedures, and related telephone numbers
- An index of manufacturers' literature and O&M instructions
- Lists of basic spare parts and supplies, and suggested inventory control and restocking procedures

- References containing additional useful information

In order to be used, the O&M manual should be simple and easy to follow. Any changes in the manual should be reviewed by the plant staff at the time they are made. The O&M manual should be used in training programs for staff.

Routine Operations

A program of routine operations should be developed for each aspect of the water system. It would include:

- A description of the task to be performed; the individual responsible for doing it; and reporting procedures

- Supplies and tools needed for the job

- A list of indicators of malfunctions

- Interrelationship with other system operations

- Emergency operations and safety precautions

Examples of routine operations may include, but are not limited to the following:

- Valve and fire hydrant testing
- Rotation of pump use
- Sample collection, analysis, and reporting
- Filter backwashing
- Carbon regeneration and lime recalcination, where applicable
- Emergency generator operation
- Safety inspections

The overall performance of the water system is the best means of assessing the adequacy of the operations program. If the water produced meets expected quality standards and can be delivered in sufficient quantity to satisfy customer demands at a reasonable cost, then it is likely that the operations program is adequate.

Maintenance

System maintenance falls into two general categories. Routine or preventative maintenance are those activities which are done on a regular, scheduled basis. They are done in accordance with a set of standardized procedures and are aimed at optimizing performance, minimizing breakdowns, and extending the useful life of facilities. Unscheduled or emergency maintenance is service required in the event of a system failure. Such activities cannot be predicted; however, emergency repairs can be greatly reduced by an effective routine maintenance program. System failures may accompany severe weather or natural disasters such as heavy rain or snow storms, high winds, flooding, etc.

As with the operation program, a good maintenance program must be developed and followed if it is to be effective. The basic program will be different for each system and perhaps different for various elements within the same system. For routine maintenance, a card system has been found effective by many utilities. In this system, each piece of equipment has an identification card with a list and description of the required work, the frequency and time when the work is to be done, who is responsible for doing the work by job category, and a recording form for maintenance work performed. The supplies, parts, tools, and other equipment needed to do the required maintenance may also be listed on the card. Other cities, such as Denver and Philadelphia use a computer system for maintenance records rather than a card system.

When performing routine maintenance, the staff should always be on the lookout for warning signs of possible malfunctions. Any abnormalities should be reported and investigated. Prompt remedial action could avert an equipment breakdown, interruption of service, or costly repairs.

A log of unscheduled maintenance and repairs should be kept. The report should include information such as the specific work down, the materials or supplies used, the length of time needed to make the repairs, the probable cause of the failure and, of course, the individuals responsible for the work. The log should be reviewed periodically to assess the adequacy of the routine maintenance program and to identify recurring weaknesses in the system. A leak or failure record of the disruption system should be kept showing the date, location, method of repair, and cause of each leak or failure.

Tools, Equipment, and Supplies

All of the tools, equipment, and supplies necessary for system operation and maintenance should be stored in a central location. The treatment plant maintenance shop or garage is the obvious storage area. The specific inventories should be selected to meet the system demands. Commonly used spare parts usually will be listed in the manufacturers' O&M literature; there may also be a list of basic tools needed for various types of maintenance and repairs.

One individual on the staff should be responsible for the supply and parts inventory. A standardized procedure should be followed to make sure orders are made to replenish stock well before they are needed. Care should be taken to use older supplies first, especially if they have limited shelf life.

Tools and equipment, particularly if small, have a tendency to be easily lost or misplaced. To minimize costly replacement and to ensure the availability of tools when they are needed, a sign-out system should be instituted. Tools should be returned to storage location if they are no longer being used.

RECORDS

Recordkeeping is an essential function of plant operations and maintenance. See Part I, Records and Reports, page 4-3.

REFERENCES

- "Basic Water Treatment Operators' Manual," AWWA Manual M18. This gives specific information on unit processes, laboratory testing, safety, etc., for water treatment plants.

- "Water Utility Management," AWWA Manual M5, Chapter 16. This discusses equipment maintenance - routine maintenance programs, spare parts, reporting forms, etc.

- "Water Distribution Training Course," AWWA Manual M8, Chapter 8. This discusses system maintenance and control, including inspection, testing, equipment, records, etc.

- "Installation, Operation, and Maintenance of Fire Hydrants," AWWA Manual M17. This short pamphlet summarizes requirements of fire hydrants.

- Manufacturers' O&M Instructions - These should be kept for all equipment; they include operating procedures, maintenance schedules, troubleshooting guides, etc.

SECTION 12.

SURVEILLANCE

The only means of ensuring the quality of the delivered water is by close, careful monitoring of the raw supply, the treatment processes, the finished water, and the product delivered to the consumer at his tap. A certain minimum surveillance of community and non-community supplies is required by law. Conscientious attention given to a comprehensive monitoring program can yield high returns in customer satisfaction, system control and operations, and economic savings.

There are three basic considerations in a good surveillance program - representative sampling, proper laboratory procedures, and careful data evaluation. Some typical questions which arise concerning surveillance follow:

1. Should a water utility provide its own laboratory and technical staff or should it contract for laboratory services with the State or a private laboratory? (See page 12-3)
2. What is one of the most frequent violations of the NIPDWR? (See insufficient number of samples collected, page 12-3).
3. What is the required frequency of sampling? (See Table 12 -1, page 12-2)

OBJECTIVES AND REGULATIONS

There are two basic reasons for monitoring a water system. The first is legal. Minimum sampling, testing and reporting requirements are dictated by the SDWA. The requirements are discussed in Section V of this report and summarized in Appendix A which contains the newly adopted primary drinking water standards. These requirements are designed to guarantee that a safe product is delivered to all water customers; they are by no means adequate to ensure that the system is run efficiently. As noted in Table 12-1, the samples are collected at different points in the distribution system. They do not reflect the basic quality of the raw water source or provide information regarding individual process operation and control.

Efficient plant operation will undoubtedly require additional monitoring. This, of course, will depend on many system-specific factors such as the sources of supply, the treatment train, the age of the system, the distribution network, the proximity of sanitary sewers, etc. Comprehensive monitoring can be cost-effective, particularly if treatment processes are not functioning properly, are being operated incorrectly, or are not needed due to seasonal or long-term changes in the raw water characteristics. Adequate testing can identify areas where the system is not performing as designed.

TABLE 12-1. REQUIRED SURVEILLANCE SAMPLING LOCATIONS AND FREQUENCY

Test	Sample location	Frequency	
		Community	Non-community
Inorganics	Consumer's faucet*	Once/year[§]	State option[†]
Organics	Consumer's faucet	Once/3 years[¶]	State option
Turbidity	At point(s) where water enters the distribution system	Daily	Daily
Coliform bacteria	Consumer's faucet	See Appendix A	Once/quarter[†]
Radiochemicals			
Natural	Consumer's faucet	Once/4 years[†]	State option
Man-made	Consumer's faucet	Once/4 years[#]	State option

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* Must be representative of conditions within the system

§ Surface water systems; groundwater only, once/3 years

† All systems

¶ Surface water systems; groundwater only, State option

# Surface water systems serving more than 100,000 people, all others, State option

Although it is not required by the SDWA or the NIPDWR, it is valuable, for operational control of the water system to provide additional surveillance. This can include weekly checks of turbidity at representative points within the distribution system, weekly total plate counts of every fifth bacteriological sample taken for coliform analysis, and measurement of chlorine residual each time that a bacteriological sample is taken.

Surveillance records provide a very valuable historical record of water system operations. Such records are critical for future planning purposes as well as for optimizing current service.

SAMPLING

A sampling program must be planned for the individual system. It is not only important that the samples be representative of the conditions which exist within the system, but they must also be collected properly and within time requirements.

The first step in developing a sampling program is to determine the minimum reporting requirements of the SDWA and the necessary source and process control monitoring. This should be compared with any existing monitoring and the deficiencies corrected. A regular schedule should be followed to ensure efficiency and consistency. Certain inaccuracies in monitoring may occur and, therefore, proper collection techniques and preservation methods should be followed to minimize these effects. One aid in this regard is to collect more than the minimum number of samples required so that one bad sample has less effect on the overall result.

Procedures for sampling are discussed in the references cited at the end of this section. If there are any questions regarding sampling procedures not addressed in these references, the state laboratory personnel should be consulted. The failure to collect the minimum number of samples required is one of the most frequent reasons for failure to meet drinking water regulations.

LABORATORY FACILITIES

As with sampling, laboratory needs are also system-specific. With two minor exceptions, the required tests and reports must be completed by a certified laboratory. The decision to maintain a laboratory or go to an outside laboratory depends on numerous factors such as, existing staff skills and facilities, the extent of monitoring for source and process control, and overall economics. In some cases, a small plant with a complex treatment system may maintain its own laboratory with the chief operator being a certified laboratory technician. In other cases, a larger system with a simple treatment scheme will opt to perform its own plant control tests and have the required tests performed by a private or governmental laboratory.

Another factor which influences the best location for laboratory testing is the kind and number of tests needed for control of plant operations. Often, if this laboratory need is met, facilities will be available to do the additional sampling and testing needed for record purposes.

The information in Table 12 -2 may be helpful for estimating the minimal laboratory requirements for various size water treatment plants. Necessary laboratory apparatus depends on the tests to be performed. Standard Methods includes a detailed list of the equipment required to run each analysis it describes (See reference at the end of this Section).

At least one member of the staff of each surface water treatment plant should be trained for turbidity even if a utility does not maintain a complete laboratory. Under the SDWA, turbidity testing is required daily for surface water supplies. This test need not be done by a certified laboratory technician, but the individual must be approved by the state. Turbidity testing follows a simple procedure and requires a minimum of equipment.

TABLE 12 -2. RECOMMENDED MINIMUM WATER PLANT LABORATORY REQUIREMENTS

Plant capacity, mgd	Laboratory floor space, sq ft	Work bench area, sq ft	Cabinet volume, cu ft
1 or less	180	12	200
1 to 5	300	18	300
5 to 10	600	24	500
10 to 25	800	30	650
25 or more	1,200	36	800

Under certain circumstances, with state approval, chlorine residual testing may be substituted for a portion of the bacteriological monitoring. As with turbidity testing, this does not require a certified laboratory technician. Using this monitoring alternative may represent a significant economic savings and should be investigated, particularly by the smaller utilities.

INTERPRETATION AND EVALUATION

The analysis of test results is important to system operation and product quality. Interpretation and reporting of required surveillance is straightforward and clearly outlined in the SDWA (see Section 5). Operational monitoring may be more complex. Certain operational changes are easily made; (many may be automatically controlled); however, some depend on accurate testing procedures and quick detection and thorough analysis of abnormal conditions.

A comprehensive surveillance program is important to efficient system management. The aim of a water utility should be to provide the best quality water for the least overall cost. Sampling and testing often represents only a small portion of the total operations cost, yet the resulting information assures safe water.

REFERENCES

- "The Safe Drinking Water Act; Self Study Handbook; Community Water Systems," AWWA, 1978. Outlines and explains the surveillance program required for compliance with the SDWA and Interim Primary Drinking Water Requirements; includes basic testing procedures and reporting procedures.
- "Methods for Chemical Analysis of Water and Wastes," U.S. EPA, Technology Transfer, 1974. Outlines procedures for monitoring water quality; includes laboratory requirements and sampling programs.
- Standards Methods for the Examination of Water and Wastewater, 14th Edition, 1976. Gives detailed information on laboratory testing procedures, equipment, reagents, safety, etc.

- "Technical Guidelines for Public Water Systems," U.S. EPA, June, 1975, NTIS #PB 255 217, Chapter IX. Gives surveillance standards for source, treatment, and supply of water, sampling and analysis requirements, reporting procedures, interpretation of results, process control, etc.

PART III

FINANCE

The cost of providing potable water is one of the most important aspects of water utility management. Without adequate financing, water systems cannot provide the service the public expects. Sufficient funds must be provided for needed new construction projects as well as for operation and maintenance of existing facilities. In addition, financial reserves must be established to meet emergency O&M needs and to offset depreciation of the water system.

Water system costs are regionally and site specific, and are unique for each utility. Long term capital expenditures and annual O&M costs must be balanced by revenues. Estimates of cash flow requirements should be made every five years and updated semi-annually.

This section of the Decision Maker's Guide summarizes cost considerations and information for all major water system expenditures. Capital costs are presented to show the magnitude of investments required to build various facilities needed for water production and delivery.

Also discussed are various means for financing projects and O&M by user charges. References are cited at the end of each section to provide additional information on budgeting and financial assessments.

PART III
FINANCE

- 13. COSTS
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  - ANNUAL COSTS – P. 8
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SECTION 13

COSTS

1. What are the major items of capital expenditure for water systems? (See page 13-1)

2. What variables affect water system costs? (See page 13-2)

3. What variables affect water use? (See pages 13-2 and 13-5)

4. What factors affect the design of water supply works, treatment plants. pumps, distribution mains, and storage structures? (See page 13-2)

5. What are some typical capital costs for water systems of various capacities? (See Table 13-1)

6. What options are there regarding source of water supply? (See page 13-2 and 13-4)

7. What factors affect the type and extent of water treatment required? (See page 13-4)

8. What water treatment processes are in common usage? (See pages 13-4 and 13-5)

9. What can be done with wastes produced during water purification? (See page 13-5)

10. What factors affect distribution, storage, and pumping costs? (See page 13-6)

11. What are the major items of annual cost in the operation and maintenance (O&M) of water systems? (See page 13-11)

12. Roughly, what are typical O&M costs? (See pages 13-11 thru 13-5)

13. What are approximate costs for monitoring and surveillance? (See pages 13-15)

CAPITAL EXPENDITURES

The major areas of capital investment in a water supply system are:

- Supply or source development and transmission
- Water treatment and wastes disposal
- Distribution
- Storage
- Metering
- Fire protection
- Administrative and Operation and Maintenance (O&M) facilities

The actual capital investment needed for any community is specific for the water system in question. Some of the primary variables which influence capital costs are: system size and geographic locations, type of service whether domestic, commercial, or industrial, characteristics of the system design, labor costs, availability of materials, and climatic and seasonal factors. Investment costs are quite variable among water systems; nevertheless, a general feeling for the relative contribution from major system components can be obtained from a summary of typical capital cost estimates. Such information is helpful for water supply management. Accordingly, this sub-section presents rough estimates of costs for major system components of a water utility.

All costs are related to design capacity of the system rather than to population served because per capita water use varies widely between humid areas with high annual rainfall and arid areas, and with industrial water requirements of different communities. The basis for capital cost estimates are included in Appendix D.

A summary of approximate capital costs for major components of a water supply system is contained in Table 13-1. Costs vary widely and are system specific. A description of each follows. All costs ued in this report are derived from an EPA Interim Report titled, "Estimating Costs As A Function of Size & Treatment Efficiency", as referenced at the end of this Section.

Supply

Conventional water supplies are normally obtained from wells, springs, impounding reservoirs, natural lakes, rivers, and streams, or a combination of these sources. The construction costs for developing each of these sources varies onsiderably. Water may also be purchased wholesale from another water purveyor.

Many cities in the United States, especially small cities, are served by groundwater (wells), and there are a large number of systems utilizing surface water supplies. Groundwater supplies may require less extensive treatment than surface waters.

- Wells - The construction cost of well water supplies varies with local conditions, such as depth, capacity, drilling conditions, distance between wells, and other characteristics; the single most important factor affecting the cost is the capacity of the system. The number of wells needed is another factor. The average cost of construction includes the wells, well houses, power supply, pumping, electrical equipment and controls, and collecting lines. For costs presented here, the pumps are assumed to be capable of lifting water to the surface with excess pressure of approximately 100 feet. Roughly, the capital expenditure for developing a well supply ranges from $0.10 to $0.80 per gpd (gallon per day) design capacity.

- Stream or lake intake - A water supply developed from a natural lake, river or stream must be adequate to supply the maximum daily demand. The estimated construction cost which follows includes the intake structure piping, pumping to supply design capacity with 100 feet rated

TABLE 13-1. SUMMARY OF ROUGH CAPITAL COSTS FOR VARIOUS SIZE WATER SYSTEMS* (In Thousands of Dollars)

Capacity, mgd (million gallons per day)	System size			
	0.1	1	10	100
	(Costs in thousands of dollars)			
Supply				
Wells	$ 80	$ 140	$1,010	$10,100
Stream or Lake Intake	160	180	950	7,890
Reservoirs	—	2,000	2,800	16,000
Treatment				
Chlorination	6	6	37	180
Filtration/Chlorination	88	652	2,170	9,690
Sed./Filt./Chlorination	134	845	3,100	17,400
Wastes Disposal				
Centrifuge/Haul	-§	297	414	1,360
Thicken/Vacuum Filter/Haul	-	291	502	1,710
Drying Beds/Haul	28	71	481	-
Liquid Hauling	69	142	647	-
Transmission	Varies widely with location			
Distribution				
Pumping	150	270	1,030	6,390
Mains	Varies widely with location			
Storage	40	90	440	3,540
Admin., Lab. & Maintenance Facilities	-	40	150	500

*The text includes a description of equipment and assumptions for each alternative. See reference at end of this section for source of estimates.

§Dashes denote conditions outside typical range of application.

discharge pressure, power supply, controls and other appurtenances. It ranges $0.80 to $1.60 per gpd design capacity.

- Impounding reservoirs - Damming of an intermittent or continuously flowing stream or river is a common method of storing water for use during seasonal low flow periods. The storage capacity must be adequate to meet average requirements thorughout the year with some safety factor. The construction cost of an impounding reservoir will be affected by local conditions, most importantly, capacity, topography, geology, stream flow characteristics, construction materials available, etc. The total cost of construction includes construction of the dam, spillway, intake tower and piping, cleaning and grubbing, fences, roads, and other necessary appurtenances. This cost varies from $0.16 to $2.00 per gpd (gallon per day) design capacity.

- Water Purchase - In some situations it may be advantageous to purchase water from another system on a wholesale basis.

Water Treatment

The need for water treatment facilities depends on the quality of the raw water. In general, surface waters cannot be used for a potable supply without treatment. As a minimum, treatment of surface water would consist of turbidity removal and disinfection. In other situations, the water may require more extensive treatment for removal of hardness, tastes, odors, color, and organic and inorganic contaminants.

Generally, groundwater sources are more constant in quality and require less treatment than surface water supplies. In many situations, groundwater may only require simple disinfection to render it potable. However, it may contain undesirable levels of substances such as flouride, nitrates, organic contaminants, total dissolved solids (TDS), iron, manganese, hydrogen sulfide, and carbon dioxide. When any of these contaminants are present in sufficient concentrations, treatment must be provided for their removal.

There are many other combinations and alternative processes which can also be used to treat a water supply. Cost curves for 30 unit processes applicable to contaminant removal are contained in an interim report prepared for EPA, entitled "Estimating Costs for Water Treatment as a Function of Size and Treatment Efficiency", August, 1978, EPA-600/2-78-182. (The final report contains costs for 99 unit processes). This reference is useful for comparing costs of alternative processes and process trains in preliminary planning. It is available from the EPA, MERL, Cincinnati, Ohio 45268.

Basic Treatment Alternatives--

Examples of basic treatment systems which are commonly used in municipal water practice industry include:

- Chlorination - Simple disinfection by chlorination is considered to be a minimal treatment system for both ground and surface water supplies. Chlorine may be applied to water in one of these forms: as elemental chlorine (chlorine gas), as hypochlorite salts, or as chlorine dioxide.

Gaseous chlorine was employed for this analysis and installed costs ranged from \$0.002 to \$0.06 per gpd (gallon per day) of capacity.

- Filtration/Chlorination - Direct filtration (with chemical filter aids) followed by chlorination may be an acceptable treatment scheme for water supplies with low turbidity and low suspended solids concentrations. For 0.1 mgd, the cost given below is for a complete pressure filter plant, including filter vessels, mixed media, piping, valves, controls, electrical system, backwash system, surface wash system, chemical feed systems (alum, polymer, and chlorine), raw water pumps (no intake structure), one-hour detention pre-filter contact basin, backwash/clearwell storage basin, building, and other ancillary items required for a complete and operable installation. For plants with a capacity of 1 mgd or greater, the costs for conventional gravity filter facilities are used. These include chemical feed systems (for alum, polymer, and chlorine), rapid mix, flocculation gravity filter structure, filter media, hydraulic surface wash system, backwash pumping facilities, wash water surge basins, in-plant pumping, and clearwell storage. Costs range from \$0.10 to \$0.88 per gpd of capacity.

- Sedimentation/Filtration/Chlorination - In estimating costs for plants under 1 mgd, the cost of a package plant is assumed, and for flows of 1 mgd and greater, conventional unit process costs are used. Package treatment plants include coagulation, flocculation, sedimentation, filtration, and chlorination all within factory preassembled units for field assembled modules. Conventional treatment includes the same process but in custom-designed units. The capital investment for this type of treatment ranges for \$0.17 to \$1.34 per gpd of capacity.

Waste Handling and Disposal

There are several methods of waste handling and disposal which can be used by a water utility. No specific method is most economical for all wastes since the properties and quantity of waste solids are a function of the quality of the water and of the chemicals added in water treatment. Very often, the selection of an economical waste disposal method will depend on the solids concentration of the waste material. Although there are other waste disposal alternatives, simplified cost estimates are presented for the following practices:

- Centrifugation and sludge hauling
- Gravity thickening, vacuum filtration, and sludge hauling
- Sand drying beds and sludge hauling
- Liquid sludge hauling
- Discharge to sanitary sewers

Dewatering and Sludge Hauling—

Mechanical dewatering by vacuum filtration or centrifugation is one possible method of handling water treatment wastes. For most small communities, high costs for equipment, operation and maintenance, and disposal of dewatered waste solids makes this alternative economically impractical. Total investment costs may range from \$10,000 to \$300,000 per mgd of plant capacity.

Sand drying beds and lagoons are more common methods of treating water treatment plant wastes, particularly in small communities. In areas where ample land is available at a relatively low cost (which is often the case near small treatment plants) natural drying can be very economical. Typical investment costs will range from $50,000 to $300,000 per mgd of plant capacity. Also, O&M costs for drying beds and lagoons are much less than for mechanical dewatering.

A haul distance of 20 miles one-way has been assumed for all cases and land costs are not included.

Liquid Sludge Hauling--

In some cases, it may be more economical to haul treatment wastes directly to a landfill or to a land appplication site as a liquid rather than following dewatering. The summary in Table 13-1 includes the capital cost in facilities for hauling liquid sludge 20 miles one way.

Discharge to Sanitary Sewer--

A popular method for disposal of water treatment plant wastes is the discharge to a sewage treatment facility via sanitary sewers. Although this method of disposal is particularly inexpensive, it may not always be feasible. In some cases, the wastewater treatment facilities may not be able to effectively treat water treatment plant wastes due to the increase in solids and volume contributed by the water utility. In this situation, the solids must be processed at the water treatment plant and disposed elsewhere. Capital costs are not shown for this alternative, although they are low. See reference at the end of this section.

Hazardous Materials--

Water treatment plant wastes containing arsenic, fluoride, or radiological wastes are considered hazardous materials and require special consideration for disposal. The Resources Conservation and Recovery Act (RCRA) regulates the disposal of these hazardous materials.

Distribution and Storage

Pumping Stations--

If the source of supply is not at an elevation adequate for gravity flow to the point of use, it is necessary to provide pumping. Pumping facilities may be located at the well; at an intake or pumping station in a lake, river, or stream; or along a pipeline between the source and the point of use.

Pumping station cost estimates which follow are for facilities located along a pipeline where heads of 100 to 240 feet may be required. Total pumping station costs are dependent upon pump capacities, energy losses, number of stations, and the estimated cost of each station.

Many factors are considered in preparing detailed cost estimates for pumping stations, including capacity, pumping head, source of power, necessary reliability, type of service, degree of instrumentation and control, aesthetic considerations, noise levels and others. Such factors are reflected to varying degrees in the average costs which range from $0.06 to $1.50 per gpd (gallon per day) of plant capacity. The estimated costs shown are for a complete pumping station, including the structure, pumping equipment, piping, electrical equipment and controls, surge protection facilities, and all other appurtenance for a complete installation. The costs presented are applicable for pumping stations built as separate structures, with heating and electrical systems and piping separate from other area facilities.

Distribution Mains--

There are numerous pipe sizes, materials and methods of operation which must be evaluated before pipelines can be designed. These factors along with local conditions such as excavation conditions and depth of cover influence transmission line costs. The costs in Table 13 -1 include pipe in place, fittings, valves~~,~~ special structures, controls, and a nominal allowance for stream, railroad, and highway crossings. These costs typically range from $0.01 to $1.00 per gpd plant capacity.

Treated Water Storage--

Treated water storage facilities should have the capacity to provide for meeting the varying rate of water demand during the day, fire reserve, and emergency reserve. Storage requirements for the cost analysis below are based on 125 percent of the design capacity of the treatment plant and would furnish a six-hour emergency supply of water at a maximum day design rate. This capacity of 125 percent of design capacity is a minimum, and where higher factors apply, they will mean higher costs.

Treated water storage often is provided in concrete tanks or above ground steel tanks. In some cases the storage is built integrally with the plant structures and in others it is built as an adjacent but separate structure. Costs will vary for different capacities, materials of construction, and different storage configurations. Storage costs may range from $0.06 to $0.40 per gallon plant capacity.

Metering

A part of the water utility's capital investment may be the purchase and installation of water meters at customer service connections. Metering serves two distinct purposes. It may reduce water demands by as much as 25 to 30 percent by creating an awareness on the part of the users of the relationship between consumption and cost. It is also necessary for any pricing system other than a flat rate.

The potential cost savings realized by reduced consumption should be considered and compared to the cost of installing and maintaining water meters at service connections. Many communities install meters for all dwelling units. The average cost to install a meter and box as part of a new system is estimated at about $94 per residential service. The cost to install a meter on an existing service may be as high as $650. The cost to read the meter and prepare a bill on a bi-monthly schedule and maintain it in good repair is estimated to be $3.50 to $4.00 per residential meter per year.

Fire Protection

Depending on the population served, design of the water system, and method used to supply required fire flows, a large capital investment by the water utility may be necessary. This investment requires equitable service charges for public and private fire protection systems since there are measurable costs and expenses associated with providing both classes of service. Although there are no strict rules for allocating these costs, there are two general methods available:

- Capacity-Ratio Method - This method assumes that fire protection and general consumption are of equal importance and value. The cost of items of a joint-use nature are shared equally between the two functions based on the relationship between the capacity required for public fire protection and the capacity required for general consumption.
- Fire Protection As An Incremental Cost Method - This method assumes that general consumption is the primary function of the water supply system. Here, basic costs are first charged to general consumption functions and the incremental costs associated with also providing fire protection are then determined.

Public charges for fire protection should be based on the incremental cost of providing that portion of the water system that contributes to fire protection, above and beyond water distribution requirements. The same methods outlined for basic supply costs should be used to determine these costs. They are not included in the summary table, Table 13-2, which follows.

Administrative and O&M Facilities

Administration buildings, garage, and shop buildings are often included in water treatment plant construction projects for small cities. These buildings are intended to house personnel; laboratories; store records, materials and tools; and enclose maintenance areas. If the department or district offices are also incorporated at the plant, additional space is required. For planning of costs associated with these buildings, it is best to determine the space requirements and use typical unit building costs (per square foot). Current costs for laboratories range from $30 to $71 per square foot with a median value of $51. Office buildings range from $28 to $47 per square foot with a median value of $37. A typical administration building, being a composite of these will probably range from $40 to $45.

ANNUAL COSTS

The annual costs of a utility include debt service for repayment of major capital financing, as well as O&M costs. Typical annual costs for water utilities are summarized in Tables 13-2 to 13-6. Estimates are shown relative to plant design capacity and are outlined for the various major components of a typical water supply system. Debt service and O&M costs are presented on a unit basis (¢/1000 gallons) to illustrate economies of scale. Debt service is computed as respective capital expenditures ammortized for 20 years at 7 percent interest.

TABLE 13-2**. SUMMARY OF APPROXIMATE TOTAL ANNUAL COSTS* (IN CENTS PER THOUSAND GALLONS) FOR POTABLE WATER TREATMENT

Plant capacity, mgd (million gallons per day)	0.1	1	10	100
		(Cents per thousand gallons)		
Chlorination				
Debt Service	1.5¢	0.2¢	0.1¢	0.05¢
O&M	5.7	0.7	0.5	0.32
Total	7.2	0.9	0.6	0.37
Filtration/Chlorination				
Debt Service	23	17	5.6	2.5
O&M	24	14	3.5	2.5
Total	47	31	9.1	5.0
Sedimentation/Filtration/ Chlorination				
Debt Service	35	22	8.0	4.5
O&M	62	14	6.0	4.9
Total	97	36	14.0	9.4
Admin., Lab. & Maintenance Facilities				
Debt Service	-§	0.9	0.3	0.1
O&M	-	5.3	1.3	0.4
Total	-	6.2	1.6	0.5

* Including debt service for capital expenditures as well as O&M.

§ Dashes denote out of typical range of application.

**Derived from information in first reference at end of this section.

For private utilities this is roughly equivalent to depreciation and return on investment. The basis for computing O&M costs is contained in Appendix E. O&M costs are itemized relative to labor, maintenance and materials, chemicals, and energy as a percentage of the total O&M expense.

As with previous cost estimates, this information is presented only to illustrate the relative magnitude of various cost for major system components; actual costs are different for each utility as influenced by local conditions.

Water Treatment

The annual costs for water treatment and on-site facilities, such as administrative, laboratories, and maintenance buildings, are summarized in Table 13-2. The cost of data service and O&M are about the same order of magnitude, and economies of scale are apparent in both. Typically, small communities employ groundwater sources of relatively high quality where simple chlorination is all the treatment necessary to meet National Interim Primary Drinking Water Regulations (NIPDWR). For this case, treatment costs are on the order of 1 to 7 ¢/1000 gallons. Larger communities using surface water sources often must provide turbidity removal prior to disinfection. Treatment costs for these facilities are about 5 to 14 ¢/1000 gallons.

Referring to Table 13-3, it is apparent that the major O&M expense for small communities is for labor. This is not the case for systems larger than 1 mgd. Here, chemical and energy costs deserve close attention. Costs for monitoring and surveillance are not included in the above estimates and will be discussed separately later.

Waste Handling and Disposal

Annual debt service and O&M costs for various means of waste disposal are summarized in Table 13-4. These costs are related to sludge disposal from treatment of relatively high turbidity water (surface waters with turbidity greater than 25 TU) that require chemical addition, sedimentation, and filtration prior to disinfection. In this regard, this summary is most applicable to system capacities greater than 1 mgd which employ surface water sources. Waste disposal costs can represent from 10 to 30 percent of the cost of potable water treatment. As with treatment costs, the expenditures for financing capital and O&M for waste disposal are of the same general order of magnitude. Although the cost of discharge to sanitary sewers is quite attractive in this summary, in many cases this option is not available.

The distribution of O&M costs for wastes disposal between labor, maintenance and materials, and energy are summarized in Table 13-5. In this summary, energy costs represent the sum of electrical power and diesel fuel for trucking operations per the assumptions in Appendix E. As mentioned, the summary is most applicable to plant sizes above 1 mgd where chemical treatment for turbidity removal is applied. O&M costs are fairly well distributed between the various components, although labor typically represents the largest expenditure.

Supply, Distribution, Storage, and Metering

Water utility costs which are not associated with treatment and waste disposal are quite significant and, in many cases, represent the major expenditure for potable water supply. These costs are summarized in Table 13-6. Source development, and distribution costs are notable components. Again, recognize that small communities typically employ groundwater sources and that communities of

TABLE 13-3. O&M COSTS FOR INDIVIDUAL POTABLE WATER TREATMENT PROCESSES AS A PERCENT OF TOTAL O&M EXPENSES

Plant capacity, mgd	0.1	1	10	100
	(Percent of total O&M expenses)			
Chlorination				
Labor	88%	63%	31%	14%
Maint. & Materials[+]	2	1	11	4
Chemicals	4	31	53	78
Energy	6	4	5	4
Filtration/Chlorination				
Labor	58	77	39	17
Maint. & Materials[+]	4	5	9	6
Chemicals	4	7	28	41
Energy	34	11	24	36
Sedimentation/Filtration/ Chlorination				
Labor	83	58	24	13
Maint. & Materials[+]	3	9	6	4
Chemicals	6	26	62	76
Energy	8	7	8	8
Admin., Lab.& Maintenance Facilities				
Labor	-[§]	80	79	76
Maint. & Materials[+]	-	11	9	10
Energy	-	9	12	14

[+] Maintenance and materials cost

[§] Dashes denote out of typical range of application

TABLE 13-4. SUMMARY OF TOTAL ANNUAL COSTS FOR WATER TREATMENT PLANT WASTES DISPOSAL*

Plant capacity, mgd	0.1	1	10	100
	(Cents per thousands gallons)			
Centrifuge/Haul				
Debt Service	-§	7.7¢	1.1¢	0.4¢
O&M	-	15.7	2.1	1.0
Total	-	23.4	3.2	1.4
Thicken/Vac. Filter/Haul				
Debt Service	-	7.5	1.3	0.4
O&M	-	6.0	1.9	0.9
Total	-	13.5	3.2	1.4
Drying Beds/Haul				
Debt Service	7.4	1.8	1.2	-
O&M	15.3	2.9	1.4	-
Total	22.7	4.7	2.6	-
Liquid Sludge Hauling				
Debt Service	17.8	3.7	1.7	-
O&M	7.7	9.1	9.1	-
Total	25.5	12.8	10.8	-
Discharge to Sanitary Sewer				
User Charge+	0.3	0.3	0.3	0.3

*Annual costs in cents per 1000 gallons. Cost of land is not included. Includes amortization of capital costs and O&M.

+User charges based upon a charge of $100 per million gallons of waste.

§Dashes denote out of typical range of application.

TABLE 13-5. O&M COSTS FOR WATER TREATMENT PLANT WASTE DISPOSAL AS A PERCENT OF TOTAL O&M COSTS

Plant capacity, mgd	0.1	1	10	100
	(Percent of total O&M expenses)			
Centrifuge/Haul				
Labor	-[§]	88%	86%	76%
Maint. & Materials[+]	-	5	5	7
Energy	-	8	9	17
Thicken/Vac. Filter/Haul				
Labor	-	45	46	42
Maint. & Materials[+]	14	11	9	-
Energy	-	32	22	29
Drying Beds/Haul				
Labor	85	86	85	-
Maint. & Materials[+]	14	11	9	-
Energy	1	negligible	7	-
Liquid Sludge Hauling				
Labor	54	56	56	-
Maint. & Materials[+]	33	32	32	-
Energy	13	13	13	-

[+] Maintenance and materials cost

[§] Dashes denote out of typical range of application

TABLE 13-6. SUMMARY OF ANNUAL COSTS FOR SUPPLY, DISTRIBUTION, AND STORAGE

Capacity, mgd	0.1	1	10	100
	(Cents per thousand gallons)			
Supply				
Wells				
Debt Service	21¢	3.6¢	2.6¢	2.6¢
O&M	26	6.6	5.1	5.1
Total	47	10.2	7.7	7.7
Stream or Lake Intake				
Debt Service	42	4.7	2.5	2.1
O&M	20	6.4	3.8	3.7
Total	62	11.1	6.3	5.8
Reservoirs				
Debt Service	206	52	7.3	4.2
Distribution				
Pumping				
Debt Service	20	3.8	1.9	0.2
O&M	20	6.5	3.9	3.8
Total	40	10.3	5.8	4.0
Transmission Line				
Debt Service	26	4.2	1.0	0.3
O&M	0.4	0.1	neg.	neg.
Total	26.4	4.3	1.0	0.3
Storage				
Debt Service	10	2.3	1.1	0.9
O&M	0.4	0.1	neg.	neg.
Total	10.4	2.4	1.1	0.9

neg. = negligible cost

more than 5,000 persons generally use surface waters or a combination of surface and groundwaters. Annual costs for source development may range from 2 to 50 ¢/1000 gallons. Similarly, distribution costs are generally in the same range. Pumping cost (when applicable) may be a major component in distribution costs. Pumping costs consist primarily of electrical energy costs which are a significant variable for different communities.

Monitoring and Surveillance

In implementing the NIPDWR, all communities will have to bear the cost of monitoring their drinking water. The total cost per capita to perform routine monitoring is illustrated in Table 13-7. Actual monitoring costs will depend on the cost per analysis and on the institutional arrangements made by each system for laboratory services. Some water utilities perform their own analyses, while others depend on state health agencies or private commercial laboratories. The monitoring costs shown in Table 13 - 7 are based on the following cost estimates:

Analysis	Cost Range ($) Per Analysis
Coliform	5 - 10
Complete Inorganic	70 - 170
Complete Organic	150 - 260

TABLE 13-7. ESTIMATED MINIMUM ANNUAL MONITORING COSTS PER PERSON SERVED VERSUS POPULATION SERVED AND TYPE OF COMMUNITY WATER SYSTEM

System size, population served	Unit cost, $/person/year Surface supply	Groundwater
25	7.20 - 15.05	3.35 - 7.05
100	1.80 - 3.75	0.85 - 1.75
500	0.35 - 0.75	0.15 - 0.35
1,000	0.20 - 0.40	0.10 - 0.20
2,500	0.15 - 0.30	0.05 - 0.15
5,000	0.10 - 0.25	0.05 - 0.15
10,000	0.10 - 0.20	0.05 - 0.15
100,000	0.05 - 0.15	0.05 - 0.15
1,000,000	* - 0.05	* - 0.05
10,000,000	* - *	* - *

*Less than $0.05

The lower values are based on costs incurred in EPA laboratories, while the higher costs are based on commercial laboratory estimates. It should be recognized that these costs are only for routine monitoring, and that additional costs will be incurred for non-compliance monitoring (monitoring required when a system exceeds a MCL) and for monitoring to control system operations.

REFERENCES

- "Estimating Costs for Water Treatment as a Function of Size and Treatment Efficiency," R.C. Gumerman, et al, EPA-600/2-78-182, Interim Report, August 1978. Contains construction and operation and maintenance cost curves for three package water treatment systems and twenty-seven unit processes; final report will have cost information on approximately 100 processes.

- "Study of the Beneficial Disposal of Water Purification Plant Sludges in Wastewater Treatment," John O. Nelson, Charles Joseph, and Russell Culp, EPA Grant No. S803336-01-0, 1977, Cincinnati, Ohio, Dr. B.V. Salotto, Project Officer.

SECTION 14

INCOME

1. What are the sources of income available to water systems? (See page 14-2)
2. What expenses must be covered by water utility income? (See page 14-1)
3. What are the rate structures for water sales? (See Table 14 -2)
4. How may ad valorem taxes be used by water utilities? (See page 14-5)

Utility revenues, including consumer service charges, should be designed to cover all system financial obligations and establish a sound credit rating that will attract future capital. They can be obtained through connection fees, direct water sales, special user charges, payments by developers, ready-to-serve charges, and taxation. There is a decreasing trend in the use of tax funds for water works. An intelligent revenue policy is intended to recover the long-term financial obligations and to distribute these costs equitably among present and future users as well as to cover Operation & Maintenance (O&M) costs. However, it is also necessary for the overall financial plan to be implemented in a practical manner within constraints of the system, system management, and customer acceptance. Therefore, different revenue programs are needed to meet the various conditions, and to continuously rebuild the water system. Special seasonal rates or drought rates may be levied. Drought rates may provide for a special surcharge with automatic termination at some maximum permitted usage.

REVENUE REQUIREMENTS

The revenue requirements for publicly owned utilities typically must cover expenses for:

- Operation and maintenance
- Debt service
- Capital improvements or additions that represent normal plant extensions
- Payments in lieu of taxes
- Contributions to other departments
- Developer refunds
- Annual capital replacements
- Reserves for major improvements including replacement of depreciated plant (reserves are usually State regulated or limited)

Whereas, the revenues of investor owned waterworks generally cover:

- Operating and maintenance expenses, including taxes
- Depreciation
- Return on investment value (typically regulated by State public utility commissions)

SOURCES OF REVENUE

A summary of the various means of obtaining revenue is contained in Table 14-1. Water sales represent the primary source of income for most utilities. Publicly owned utilities also issue special user charges or levy taxes in order to recover facility costs which are specific to certain users. These may include fire protection, main extensions, ready-to-serve charges or connection charges. Some communities use taxation as a primary source of revenue, although this practice is generally not recognized as an efficient allocation of costs among users because such charges are a function of property value and not water use and there is great competition for tax monies. Revenue can also be raised through outside investments or interest on bank loans. A discussion of the various types of rate structures and means of taxation follows.

Water Sales

The primary source of revenue for most utilities is through direct water sales. This is generally recognized as the most equitable means of distributing service costs among consumers because rates may be structured to account for fixed service, commodity, and ready-to-serve costs.

- Fixed charges include meter reading, billing, accounting, and other services that are not a function of use.
- A commodity charge is based on the amount of water actually used during a billing period.
- A ready-to-serve charge accounts for service costs that are associated with construction to meet water system needs especially with those to meet peak demand requirements.

Many utilities structure water rates to reflect the different service needs and costs of the various consumer classes. Residential users typically have a higher demand factor (ratio of peak to average use) than large industrial users. A high demand factor requires extra system capacity on a ready-to-serve basis; therefore, residential users are typically charged higher unit-volume rates in order to recover the associated costs. Ready-to-serve charges may also be levied on vacant lots where service is provided but unused. Other system costs may be specific to certain users and charged accordingly. Fire service is one example. All community residents benefit from public fire protection; however, some benefit preferentially due to higher property value. Such costs may be apportioned through service charges or taxes. Private fire protection charges are generally handled separately from standard service on a relative, available- protection basis. The rate making policies of almost all investor-owned utilities are regulated by state commissions, and some states also regulate publicly owned utilities.

Table 14 -2 summarizes the predominant rate structures employed for water sales in the U.S. Medium and large utilities typically employ metered sales, using a declining block rate structure. The declining block structure is often used, but is being increasingly questioned as an equitable means of allocating

TABLE 14 -1. SUMMARY OF REVENUE SOURCES AND APPLICATION

Sources	Types	Comments and typical applications
Water Sales	Metered -Declining Block* -Inverted Block -Fixed Block Flat Rate	Principal source of revenue; usually structured to achieve customer equity, promote efficient allocation of resources, and discourage waste, except that flat rate may not discourage waste
Special User Charges	Fire Protection Connection Fee Local Facility Improvements or Extensions	Charges allocated to the specific users of special services, facility extensions, or connection costs
Taxes	Ad Valorem Property Special Assessment Districts Municipal Utility	Generally available to publicly owned utilities; typically employed for financing special services such as main extensions, fire, aid for major improvements, etc.
Miscellaneous	Interest on reserves and sinking funds or Investments	Publicly owned and investor owned utilities

*Presently being questioned as an equitable means of allocating costs.

TABLE 14 -2. RATE STRUCTURES FOR WATER SALES

Service type	Rate structure	Description	Discussion
Metered	Declining Block	Charge per unit volume lower for larger water users	One commonly used means of distributing costs among consumers, but does not promote conservation
	Inverted Block	Charge per unit volume higher for larger water users	Promotes conservation
	Fixed Block	Charge per unit volume regardless of volume used	Balanced approach between declining and inverted block rate structures
Flat Rate	Uniform Rate	Same charge per customer	Least expensive and simple to administer as meters or meter readers are not required, but savings may be offset if water is wasted, because of greater production requirements resulting
	Modified	Charge per customer based upon physical features that indicate relative consumption such as number of residents, rooms, or fixtures	Advantages of uniform flat rate but with charges in proportion to water use potential

costs. The inverted block structure has the advantage of promoting conservation, especially among large users.

Flat rate service does not require meters or meter reading. This may be a significant advantage, especially for small utilities. This rate structure is obviously the easiest to administer; however, it has little regard for services required by individual users and may promote water waste. In order to improve equity in cost allocation, some municipalities employ a modified flat rate structure that apportions costs according to number and type of plumbing fixtures, inhabitants, or rooms. Flat rates may encourage water waste and encroach on plant capacity.

Taxes

Taxes represent an indirect source of financing employed in combination with service charges, usually for providing fire service, assessments for service access to specific properties, and, on occasion, as an aid for constructing major improvements. Waterworks services may be funded through ad valorem property taxes, special assessment taxes, and municipal utility taxes.

An ad valorem property tax is based on assessed property values; therefore, although in some cases it well represents actual costs of consumer services (e.g., fire protection), more often, it does not represent an equitable distribution of costs.

Special assessment taxes are generally employed for service extensions or fire protection to specific regions which benefit directly from the additional service. They may be based on front property footage. They may also be levied on an ad valorem basis. This method has the advantage of distributing special costs equitably among present and future users of the special appurtenances.

A municipal utility tax may be levied relative to one or more of a community's utilities, whether public or private.

REFERENCES

- "Water Utility Management," AWWA Manual M5. Chapter 11 details the procedures for developing an equitable water rate structure.
- "Water Rates Manual," AWWA Manual M1. Includes discussions of revenue requirements, distribution of costs, and design of rate structures.

SECTION 15

FINANCING CAPITAL COSTS

1. What are the general ways of financing water utility capital costs? (See page 15-2)
2. What state and Federal help is available? (See page 15-2)
3. What kinds of bonds can water utilities sell? (See page 15-3)
4. What are the capital financing options for municipal and private water utilities? (See Table 15-1)

There are numerous means of financing capital improvements for water utilities. These vary with the ownership of the utility and the cost of the improvements. Considering the complexity of financing, the recommendations of a professional financial consultant can prove very valuable in the development of a sound financial program. This is particularly true for smaller utilities that lack the in-house expertise of larger utilities and municipal agencies.

Publicly owned water utilities typically obtain financing through bonds, industrial revenue bonds, advances from developers, government loans and grants, and working capital. Privately owned utilities have the option of selling stock, obtaining bank loans, or using revenue reserves. In either case, financing capital improvements is easier if the utility has a sound credit base.

In January 1979, the Office of Drinking Water (WH-550), U.S. EPA, Washington, D.C. 20460, prepared a summary entitled "Financial Assistance Alternatives For Water Supplies." It describes the federal financial assistance available from:

1. Farmers Home Administration
2. Soil Conservation Service, U.S. Dept. of Agriculture
3. Corps of Engineers
4. Economic Development Administration
5. Dept. of Housing & Urban Development
6. Federal Disaster Administration
7. Indian Health Service
8. Bureau of Reclamation
9. Small Business Administration
10. Dept. of Interior, Office of Water Research and Technology
11. Dept. of Labor
12. Dept of Health, Education, and Welfare
13. Office of Revenue Sharing

This summary may be obtained by writing to EPA at the address given above.

BONDS

The sale of bonds is the most common method for publicly owned utilities to finance major capital improvements. They are serviced by taxes, assessments, or revenues, depending on the financial policy of the utility. The three types of bonds are discussed below; each has certain advantages and disadvantages as given in Table 15-1.

- General Obligation Bonds - General obligation bonds are backed by the full taxing power of the issuer, with ad valorem or general property taxes generally used to repay them, although they are often repaid from utility revenues. In the latter case general obligation bonds are used rather than revenue bonds because of lower interest rates. They ordinarily require the approval of the electorate, are limited to some percentage of the taxing power of the issuer, and become part of the municipal debt. General obligation bonds are generally serial bonds which mature on a sliding scale. They offer the most flexible and least costly means of major capital financing.

- Revenue Bonds - Revenue bonds are issued on the condition that the interest and redemption charges will be paid from the revenues of the facility. These can be issued as term or serial bonds. If term bonds are issued, the term should be equal to the life of the facilities. Revenue bonds have a higher risk associated with them than general obligation bonds, therefore the interest rates are usually higher. In some states there are no legal limits on the amount of revenue bonds issued by a utility however, in every case, the revenue potential of the facilities should be carefully assessed prior to issuance of the bonds.

- Special Assessment Bonds - Special assessment bonds may be issued to pay for specific capital improvements in a portion of a service area. The bonds are paid by a special tax assessment levied on the basis of benefit in the area benefiting from the improvements. These bonds carry a higher risk and therefore a higher interest rate than general obligation bonds, since they may not be backed by the general taxing authority.

GRANTS AND LOANS

At various times, federal and state grants and loans are available for water system improvements. These programs are subject to a variety of constraints and limitations. However, they can provide a viable, low cost means of capital financing. Since they change frequently, it is not practical to describe them in detail. In recent years, the Farmers Home Administration (FmHA) and the Department of Housing and Urban Development (HUD) have had numerous financing programs available for all types of public works construction. Information on current programs may be available through a financial consultant or by inquiry to the reference given on page 15-4.

TABLE 15-1. CAPITAL FINANCING OPTIONS

Type of financing	Advantages	Disadvantages	Comments
PUBLICLY OWNED UTILITY			
General Obligation Bond (G.O.)	High flexibility, low cost. No detailed technical or economic documentation of facilities. Easily marketed. Personal income tax deduction.	Must receive voter approval. (2/3 majority in some states) Cannot exceed issuer's debt limit. Issuer must be able to levy ad valorem property tax.	Backed by full credit of issuer so risk is low. Generally, not feasible for less than $500,000. Numerous small projects can be funded by a single bond.
Revenue Bonds	Can be used to finance projects outside city boundaries. No limit on amount.	Must receive 50% voter approval in some states. Extensive facility information requirements. Outside consultant must prepare technical and economic analysis. Generally higher interest than G.O. Bonds, and greater reserve requirements. Less flexibility than G.O. bonds; higher risk.	Can be used by institutions lacking power to tax. Can be used by municipalities when their debt limit has been reached. Minimum effective issue of $1 million.
Special Assessment Bonds	Only those directly benefiting from improvement pay, and then only in proportion to benefit. No vote necessary.	Generally, not backed by full credit of taxing authority. Higher risk.	Used when facilities only serve a portion of the total service area.
Grants & Loans	May carry low interest rates.	Subject to availability and much regulation; grantor may place conditions on grant or loan.	May be limited to certain types or sizes of projects.
PRIVATELY OWNED UTILITY			
Stock Sales	Less costly than bank loans.	Reduces control of corporate decision-makers. May not have sound economic basis to attract potential buyers.	More applicable to larger private utilities. Attractive to conservative investors. Must obtain approval of PUC or Federal Securities and Exchange Commission to issue new securities.
Bank Loans	Small scale, short-term capital.	High interest cost.	Primarily used by very small utilities with no other means of financing capital improvements.
BOTH			
Revenue Reserves	Least complex method of financing. No formal financial documents.	Consumer use rates higher. Current users paying for future system.	Good for small-scale projects, routine improvements, etc.

REVENUE RESERVES

Revenue reserves or working capital can be used to finance improvements; however, using this as a source of capital funds does have limitations. In general, revenue reserves are only used on a short-term basis and not for major improvements. Even when the cash is available to make major improvements, it may be advisable to secure other long-term financing, thereby establishing a good credit record.

Connection fees are often used to build revenue reserves. New customers are charged for a share of prior capital investments made by the utility. The costs of special services such as the extension of lines may also be included in the connection fee.

Many water utilities annually commit 10 percent of their revenues to replacement repairs, many of which are constructed using the utility's employees.

STOCK SALES

Many times, the only means by which a privately owned water utility can finance major improvements is by the sale of stocks, either preferred or common. A sound utility with a good earning record attracts more conservative investors than the more erratic industrial and business market.

BANK LOANS

For the small private utility, selling stock is not necessarily a viable means of obtaining capital funds. If the company is willing to sell common stock, there are not always willing buyers. Bank financing is often the only means of obtaining capital funds. Short- or long-term notes and mortgages are issued at or above the prime interest rate.

REFERENCES

- "Water Utility Management," AWWA M5 Chapters 9 and 10. Discussion of various means of financing publicly (Chapter 9) and privately (Chapter 10) owned water utilities; includes taxation, bonds, government loans and grants, bank loans, stock sales, etc.

- "Financial Assistance Alternatives For Water Supplies," U.S. EPA, Office of Water Supply (WH-550), Washington, D.C. 20460.

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APPENDIX A

NATIONAL INTERIM PRIMARY DRINKING WATER REGULATIONS
(NIPDWR)

TABLE A-1
IPDWR MAXIMUM CONTAMINANT LEVELS FOR PUBLIC WATER SUPPLIES

Type of contaminant (community systems)	Type of contaminant (non-community systems)	Maximum contaminant levels (MCLs)		Monitoring Requirement§
Inorganic Chemicals All Water Systems†	Inorganic Chemicals All Water Systems--† Nitrate only* (all other contaminants at state option)	● Arsenic	0.05 mg/l	Surfacewater: every year Groundwater: every 3 years
		● Barium	1. mg/l	
		● Cadmium	0.010 mg/l	
		● Chromium	0.05 mg/l	
		● Lead	0.05 mg/l	
		● Mercury	0.002 mg/l	
		● Selenium	0.01 mg/l	
		● Silver	0.05 mg/l	
		● Nitrate (as N)	10. mg/l	
		● Fluoride (Annual average of maximum daily air temperatures.)		
		a) 53.7F & below	2.4 mg/l	
		b) 53.8-58.3F	2.2 mg/l	
		c) 58.4-63.8F	2.0 mg/l	
		d) 63.9-70.6F	1.8 mg/l	
		e) 70.7-79.2F	1.6 mg/l	
		f) 79.3-90.5F	1.4 mg/l	
Organic Chemicals	Organic Chemicals (at state option)	● Endrin	0.0002 mg/l	Surfacewater only: every 3 years or more frequent at state discretion
		● Lindane	0.004 mg/l	
		● Methoxychlor	0.1 mg/l	
		● Toxaphene	0.005 mg/l	
		● 2, 4-D	0.1 mg/l	
		● 2, 4, 5-TP (Silvex)	0.01 mg/l	
Turbidity Surface Water Systems Only	Turbidity Surface Water Systems Only	● 1 TU monthly average (up to 5 TU monthly average may apply at state option); OR ● 5 TU average of 2 consecutive days		Surfacewater: daily Groundwater: as specified by state
Microbiological Contaminants All Water Systems†	Microbiological Contaminants All Water Systems†	When using membrane filter test: ● 1 colony/100 ml for the average of all monthly samples; and ● 4 colonies/100 ml in more than 1 sample if less than 20 samples are collected per mo.; OR ● 4 colonies/100 ml in more than 5% of the samples if 20 or more samples are examined per mo. When using multiple-tube fermentation test: (10-ml portions) ● Coliform shall not be present in more than 10% of the portions per mo.; ● Not more than 1 sample may have 3 or more portions positive when less than 20 samples are examined per mo.; OR ● Not more than 5% of the samples may have 3 or more portions positive when 20 or more samples are examined per mo.		
Radiological Contaminants (Natural)-- All Water Systems†	Radiological Contaminants (Natural)-- (at state option)	● Gross Alpha	15 pCi/l	Every 4 years
		● Combined Ra-226 and Ra-228	5 pCi/l	
Radiological Contaminants (Man-made)-- Surface Water Systems Serving Populations Greater Than 100,000	Radiological Contaminants (Man-made)-- (at state option)	● Gross Beta	50 pCi/l	
		● Tritium	20,000 pCi/l	
		● Strontium-90	8 pCi/l	

*For all non-community water systems, initial sampling and testing must be conducted for nitrates. Routine testing, however, is at state option.

†Systems using surface and/or groundwater.

§For microbiological monitoring requirements; see Table A-2.

TABLE A-2

COLIFORM SAMPLES REQUIRED PER POPULATION SERVED

Population served	Minimum no. of samples per mo.	Population served	Minimum no. of samples per mo.
25 to 1,000[†]	1	90,001 to 96,000	95
1,001 to 2,500	2	96,001 to 111,000	100
2,501 to 3,300	3	111,001 to 130,000	110
3,301 to 4,100	4	130,001 to 160,000	120
4,101 to 4,900	5	160,001 to 190,000	130
4,901 to 5,800	6	190,001 to 220,000	140
5,801 to 6,700	7	220,001 to 250,000	150
6,701 to 7,600	8	250,001 to 290,000	160
7,601 to 8,500	9	290,001 to 320,000	170
8,501 to 9,400	10	320,001 to 360,000	180
9,401 to 10,300	11	360,001 to 410,000	190
10,301 to 11,100	12	410,001 to 450,000	200
11,101 to 12,000	13	450,001 to 500,000	210
12,001 to 12,900	14	500,001 to 550,000	220
12,901 to 13,700	15	550,001 to 600,000	230
13,701 to 14,600	16	600,001 to 660,000	240
14,601 to 15,500	17	660,001 to 720,000	250
15,501 to 16,300	18	720,001 to 780,000	260
16,301 to 17,200	19	780,001 to 840,000	270
17,201 to 18,100	20	840,001 to 910,000	280
18,101 to 18,900	21	910,001 to 970,000	290
18,901 to 19,800	22	970,001 to 1,050,000	300
19,801 to 20,700	23	1,050,001 to 1,140,000	310
20,701 to 21,500	24	1,140,001 to 1,230,000	320
21,501 to 22,300	25	1,230,001 to 1,320,000	330
22,301 to 23,200	26	1,320,001 to 1,420,000	340
23,201 to 24,000	27	1,420,001 to 1,520,000	350
24,001 to 24,900	28	1,520,001 to 1,630,000	360
24,901 to 25,000	29	1,630,001 to 1,730,000	370
25,001 to 28,000	30	1,730,001 to 1,850,000	380
28,001 to 33,000	35	1,850,001 to 1,970,000	390
33,001 to 37,000	40	1,970,001 to 2,060,000	400
37,001 to 41,000	45	2,060,001 to 2,270,000	410
41,001 to 46,000	50	2,270,001 to 2,510,000	420
46,001 to 50,000	55	2,510,001 to 2,750,000	430
50,001 to 54,000	60	2,750,001 to 3,020,000	440
54,001 to 59,000	65	3,020,001 to 3,320,000	450
59,001 to 64,000	70	3,320,001 to 3,620,000	460
64,001 to 70,000	75	3,620,001 to 3,960,000	470
70,001 to 76,000	80	3,960,001 to 4,310,000	480
76,001 to 83,000	85	4,310,001 to 4,690,000	490
83,001 to 90,000	90	More than 4,690,001	500

Source: EPA

[†] A community water system serving 25 to 1,000 persons, with written permission from the state, may reduce this sampling frequency, except that in no case shall it be reduced to less than one per quarter. The decision by the state will be based on a history of no coliform bacterial contamination for that system and on a sanitary survey by the state showing the water system to be supplied solely by a protected groundwater source, free of sanitary defects.

APPENDIX B

PROPOSED REVISIONS TO NIPDWR (NATIONAL INTERIM PRIMARY DRINKING WATER REGULATIONS)

APPENDIX B

PROPOSED REVISIONS TO NIPDWR

In the Federal Register of July 19, 1979, EPA published propcsed revisions to the NIPDWR. The Summary of these proposals follows:

"These proposed regulations amend the National Interim Primary Drinking Water Regulations (NIPDWR), promulgated according to Section 1412 of the Safe Drinking Water Act, as amended, 42 U.S.C. § 300f et seq. at 40 FR 59566 (December 24,1975) and 41 FR 28402 (July 9, 1976). These proposed amendments provide greater latitude to small public water systems for determination of compliance with the microbiological maximum contaminant levels (MCLs), specify alternative analytical techniques that have been approved by EPA for determining compliance with existing maximum contaminant levels, endorse fluoridation practices and add a statement to the NIPDWR clarifying the apparent contradiction between setting a MCL for fluoride and the beneficial uses of fluoride, add a statement to the NIPDWR that water samples taken by the State may be used to determine compliance, add a statement to the NIPDWR that clarifies that water systems shall submit to the State upon request any records required to be maintained by the NIPDWR, require water systems that have completed a public notification to submit to the State a representative copy of the public notification, change the time when results of monitoring are requried to be submitted to the State, required community water systems to conduct monitoring and reporting for sodium levels in finished drinking water and require community water systems to implement corrosion control programs under State direction.

Modifications to the NIPDWR relating to non-community water systems are also proposed. These proposed amendments increase the latitude of the States with regard to non-community water systems by providing an additional year for completion of nitrate monitoring, allow some non-community systems to exceed the 10 mg/l nitrate level up to 20 mg/l under certain controlled conditions, provide latitude in turbidity monitoring requirements and include modifications to the bacteriological monitoring frequency and public notification measures.

In addition, increased latitude is provided to the States with respect to requirements concerning public notification through the media for community water systems."

APPENDIX C

SECONDARY DRINKING WATER STANDARDS

TABLE C-1
SECONDARY MAXIMUM CONTAMINANT LEVELS FOR PUBLIC WATER SYSTEMS*

Contaminant	Level
Chloride	250 mg/l
Color	15 color units
Copper	1 mg/l
Corrosivity	Non-corrosive
Foaming Agents	0.5 mg/l
Iron	0.3 mg/l
Manganese	0.05 mg/l
Odor	3 Threshold Odor Number
pH Range	6.5-8.5
Sulfate	250 mg/l
Total Dissolved Solids	500 mg/l
Zinc	5 mg/l

*Monitoring is suggested at frequencies for inorganic contaminants in the primary regulations, annually for surface waters, and every three years for groundwaters. More frequent monitoring may be appropriate for specific contaminants as requested by the State.

APPENDIX D

BASIS FOR CAPITAL COSTS COMPUTATIONS

APPENDIX D

BASIS FOR CAPITAL COSTS COMPUTATIONS

Construction costs for most facilities fall under the following categories which are employed in this evaluation:

- Excavation and sitework includes work related to the applicable process, not general sitework such as sidewalks, roads, driveways, or landscaping.
- Manufactured equipment includes the estimated purchase cost of pumps, drives, process equipment, specific purpose controls, and other items which are factory made and sold with equipment.
- Concrete includes the delivered cost of ready mix concrete and concrete forming materials.
- Steel includes reinforcing steel for concrete and miscellaneous steel not included with manufactured equipment.
- Labor associated with installing manufactured equipment, piping and valves, constructing concrete forms and placing concrete, and reinforcing steel.
- Pipes and valves includes the purchase of cast iron pipes, steel pipe, valves, fittings, and associated support devices.
- Electrical and instrumentation includes the cost of process electrical equipment and wiring and general instrumentation associated with other process equipment.
- Housing represents all material and labor costs associated with the buildings, including heating, ventilating, air conditioning, lighting, normal convenience outlets, and the slab and foundation.

In this analysis, the capital cost factors were:

- 10 percent for engineering
- 5 percent for sitework,, piping, etc.
- 12 percent for general contractor's overhead
- 5 to 7 percent for legal, fiscal, and administration
- 7 percent of capacity cost for interest during construction (current interest rates are higher)

The costs are current as of October, 1978. Table D-1 summarizes the cost indices used in determining the construction costs.

TABLE D-1. COST INDICES AS OF OCTOBER 1978

Category	Source	Value
Excavation and sitework	ENR* skilled labor	247.0
Manufactured equipment	BLS** #114	221.3
Concrete	BLS #132	221.1
Steel	BLS #101.3	262.1
Labor	ENR skilled labor	247.0
Pipes & valves	BLS #114.901	236.4
Electrical & instrumentation	BLS #117	167.5
Housing	ENR building cost	254.8

*Engineering News Record
**Bureau of Labor Statistics

APPENDIX E

BASIS FOR ANNUAL O&M COST COMPUTATIONS
(OPERATION AND MANTENANCE)

APPENDIX E

BASIS FOR ANNUAL OPERATION & MAINTENANCE (O&M) COSTS COMPUTATIONS

The annual costs for operating and maintaining a water utility are highly variable, depending on local conditions. However, certain basic elements are common to all operations. These include:

- Labor
- Maintenance materials
- Energy

The total O&M costs for the common treatment processes are a composite of labor, maintenance materials (including chemicals), and energy costs. They do not, however, include the cost of monitoring and surveillance to comply with the SDWA requirements, nor do they include administrative costs.

LABOR

The labor requirements represented in the O&M cost curves indicate the total requirement to adequately operate and maintain the facilities. Manhour requirements for the treatment facilities are based on desirable levels of operator attention for each type of plant, with some allowance made for both preventive and unscheduled maintenance activities. The annual payroll manhours are based on 2,080 hours per year and an hourly rate of $10/hour (salary and fringe benefits) was used to convert manhours to an annual cost.

MAINTENANCE MATERIALS AND SUPPLIES

Maintenance material costs include the cost of periodic replacement of component parts necessary to keep the treatment facilities operating and functioning properly. Examples of maintenance material items included are valves, motors, instrumentation, and other process items of similar nature. The maintenance material requirements do not normally include the cost of chemicals required for process operation. Chemical costs are included as part of the total O&M costs based on the following:

Chemical	Cost
Lime	$40/ton
Alum	$70/ton
Chlorine	$300/ton
Sodium Hypochlorite	$650/ton
Polymer	$2/lb
Salt	$30/ton
NaOH	$200/ton

It should be noted however, that for small treatment facilities, the cost of chemicals will be significantly higher than the estimates shown above. Table E-1 provides more realistic chemical costs for use by small treatment systems.

TABLE E-1. WATER TREATMENT CHEMICAL COSTS FOR SMALL TREATMENT SYSTEMS

Chemical	Packaging size	Cost*
Activated Carbon (Powdered)	65 lb bags	1-14 bags, 44.45 cents per lb 15-28 bags, 41.95 cents per lb 29-50 bags, 39.45 cents per lb
Alum	100 lb bags	1-9 bags, $16 per bag 10-20 bags, $11 per bag 21-100 bags, $9.25 per bag
Chlorine	100 lb cylinders	1-9 cylinders, $30 per cylinder 10-24 cylinders, $26 per cylinder
Hydrated Lime	50 lb bags	1-40 bags, $2.85 per bag 41-200 bags, $2.23 per bag
Polymer (dry)	50 lb & 100 lb bags	varies,use $2.25 per lb
(wet)	55 gallon drums	varies, use $0.30 per lb

*Based on January 1977 price levels

Energy requirements include both process energy and building related energy. To determine a total annual energy cost, energy requirements first must be computed in terms of kw-hr per year for electricity, and cubic feet per year for natural gas. For the O&M estimates an average building-related demand of 102.6 kwh-hr/sq ft/yr was used. Process electrical energy and natural gas requirements were calculated using manufacturers' data for different treatment plant components. The total energy requirements were then converted to an annual cost based on $0.03/kw-hr for electricity, $1.20/1000 cu ft for natural gas, and $0.45/gal for Diesel fuel. Current prices for natural gas and Diesel fuel are higher.

- Chlorine Gas Disinfection
  2 mg/l chlorine dose
  <1 mgd - direct feed without storage
  1-100 - direct feed with cylinder storage

- Direct Filtration/Chlorination
  <1 mgd - package gravity filter plant
  1-100 mgd - conventional unit process facilities
  all capacities - 20 mg/l alum dose
  - 0.1 mg/l polymer dose
  - 2 mg/l chlorine dose

- Sedimentation/Filtration/Chlorination
  <1 mgd - package complete treatment plant
  1-100 mgd - conventional unit process facilities
  all capacities - 50 mg/l alum dose
  - 0.2 mg/l polymer dose
  - 2 mg/l chlorine dose
  - 20 mg/l sodium hydroxide dose

- Waste Processing and Disposal
  all capacities - haul distance 20 miles, one-way

  Mechanical Dewatering
  all capacities - gravity thickening prior to basket centrifuge or vacuum filtration
  - dewatering

  Sand Drying Beds
  all capacities - land cost not included

  Liquid Sludge Hauling
  1-100 mgd - gravity thickening prior to hauling

  Discharge to Sanitary Sewer
  all capacities - existing sewers used; sludge concentration 5,000 mg/l
  - user charge of $100/mil gal waste treated

F

APPENDIX F

RATIONALE FOR NATIONAL INTERIM PRIMARY DRINKING WATER REGULATIONS

TABLE F-1 RATIONALE FOR NATIONAL INTERIM PRIMARY DRINKING WATER REGULATIONS

TYPE OF CONTAMINANT	NAME OF CONTAMINANT	HEALTH EFFECTS OF CONTAMINANTS	BASIS FOR ESTABLISHING MCL*	SOURCES
INORGANIC CHEMICALS	Arsenic	Long term - Small sores on the hands and soles of the feet, sometimes developing into cancers. Short term- 100 mg causes severe poisoning	10% of typical daily intake	Well water, natural mineral deposits, pesticides, herbicides
	Barium	Long term - Increased blood pressure, and nerve block Short term- 550 mg is fatal dose	No effect level extrapolated from threshold limit in air	Ore deposits, metallurgical industry, paint industry
	Cadmium	Long term - Concentrates in liver, kidneys, pancreas, and thyroid; hypertension is a suspected health effect Short term- Serious illness at 13 mg/l in food	27% of typical daily intake	Electroplating, galvanized pipe, food
	Chromium	Long term - Skin sensitization, kidney damage	Reasonable safety factor to prevent dermal effects	Wastes from chrom-plating shops, cross connections to chromate-treated cooling water
	Lead	Long term - Constipation, loss of appetite, anemia, tenderness, pain & gradual paralysis in the muscles, especially the arms. Cumulative poison. Use of water with more than 2 mg/l for 3 months can be harmful.	Safety factor of 2 for long term exposure 25% of typical daily intake	Food, air, water, tobacco smoke, lead pipe
	Mercury	Long term - Inflammation of the mouth and gums. Swelling of the salivary glands, loosening of teeth. Mercury poisoning may be acute or chronic	Safety factor of 10 for chronic effects. 13% of typical daily intake	Ubiquitous in environment as result of use in industry and agriculture. Chlor-alkali mfg. plants. Slimicides. Mercurial seed treatment
	Selenium	Long term - Red staining of fingers, teeth and hair, general weakness, depression, irritation of the nose and throat	Safety factor of 3. 10% typical intake	Shallow well waters. Natural in soils
	Silver	Long term - Permanent grey discoloration of skin, eyes, and mucous membranes	Silver is held indefinitely in body tissue. MCL is set to avoid discoloration with lifetime exposure	Water disinfection
	Fluoride	Long term - Stained spots on the teeth (mottling)-the amount of discoloration depends on the amount of fluoride ingested Short term- Lethal dose is 2,000 mg/l	Long and extensive experience with natural fluoride waters	Natural occurence in deep well waters
	Nitrate (as N)	Short term- Serious or fatal blood disorder in infants, In excess amounts of (500 mg/l or greater)-irritation of the mucous lining of the gastrointestinal tract and bladder.	To protect majority of infants. Does not appear to have safety factor for all infants	Natural occurence, principally in shallow wells and springs, fertilizers, septic tanks and wastewater effluent
ORGANIC CHEMICALS	CHLORINATED HYDROCARBONS-PESTICIDES			
	Endrin	Long term - Cause symptoms of poisoning which differ in intensity. The severity is related to concentration of the chemicals in the nervous system, primarily in the brain. Mild exposure causes headaches, dizziness, numbness and weakness of the extremities. Severe exposure leads to spasms involving entire muscle groups, leading in some cases to convulsions. Suspected of being carcinogenic.	20% of safe level of intake-pending complete survey	Pesticides
	CHLOROPHENOXYS-HERBICIDES			
	2, 4-D 2, 4, 5-D	Long term - Liver damage, gastrointestinal irritation	50% of safe level of intake-pending complete survey	Herbicides
TURBIDITY	Turbidity	Short term- Interferes with the disinfectin process by shielding organisms, therefore possibly exposing the consumer to disease causing organisms	Minimum level to permit effective disinfection and to maintain chlorine residual during distribution	
MICROBIOLOGICAL CONTAMINANTS	Coliform Bacteria	Short term- The presence of these bacteria indicate that disease-causing organisms may be present in the water	Bacteriological safety	Fecal pollution of water sources, or contamination of water in distribution systems through cross-connections
RADIOLOGICAL CONTAMINANTS	Natural Gross alpha Combined Ra - 226 and Ra - 228	Long term - Bone cancer	Based on estimates of risk, pending complete survey	Natural radionuclides, nuclear weapons, nuclear fuels, pharmaceuticals
	Man-made Gross beta activity Tritium Strontium - 90	Long term - Bone cancer		

*Based on daily human intake of 2 liters of water per day

federal register

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PART IV:

ENVIRONMENTAL PROTECTION AGENCY

■

WATER PROGRAMS

National Interim Primary Drinking Water Regulations

WEDNESDAY, DECEMBER 24, 1975
FRIDAY, JULY 9, 1976
Thursday, November 29, 1979
Tuesday, March 11, 1980
Wednesday, August 27, 1980

P4-1

Subpart A—General

§ 141.1 Applicability.

This part establishes primary drinking water regulations pursuant to section 1412 of the Public Health Service Act, as amended by the Safe Drinking Water Act (Pub. L. 93-523); and related regulations applicable to public water systems.

§ 141.2 Definitions.

As used in this part, the term:

(a) "Act" means the Public Health Service Act, as amended by the Safe Drinking Water Act, Pub. L. 93-523.

(b) "Contaminant" means any physical, chemical, biological, or radiological substance or matter in water.

(c) "Maximum contaminant level" means the maximum permissible level of a contaminant in water which is delivered to the free flowing outlet of the ultimate user of a public water system, except in the case of turbidity where the maximum permissible level is measured at the point of entry to the distribution system. Contaminants added to the water under circumstances controlled by the user, except those resulting from corrosion of piping and plumbing caused by water quality, are excluded from this definition.

(d) "Person" means an individual, corporation, company, association, partnership, State, municipality, or Federal agency.

(e) "Public water system" means a system for the provision to the public of piped water for human consumption, if such system has at least fifteen service connections or regularly serves an average of at least twenty-five individuals daily at least 60 days out of the year. Such term includes (1) any collection, treatment, storage, and distribution facilities under control of the operator of such system and used primarily in connection with such system, and (2) any collection or pretreatment storage facilities not under such control which are used primarily in connection with such system. A public water system is either a "community water system" or a "non-community water system."

(i) "Community water system" means a public water system which serves at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents.

(ii) "Non-community water system" means a public water system that is not a community water system.

(f) "Sanitary survey" means an on-site review of the water source, facilities, equipment, operation and maintenance of a public water system for the purpose of evaluating the adequacy of such source, facilities, equipment, operation and maintenance for producing and distributing safe drinking water.

(g) "Standard sample" means the aliquot of finished drinking water that is examined for the presence of coliform bacteria.

(h) "State" means the agency of the State government which has jurisdiction over public water systems. During any period when a State does not have primary enforcement responsibility pursuant to Section 1413 of the Act, the term "State" means the Regional Administrator, U.S. Environmental Protection Agency.

(i) "Supplier of water" means any person who owns or operates a public water system.

(j) "Dose equivalent" means the product of the absorbed dose from ionizing radiation and such factors as account for differences in biological effectiveness due to the type of radiation and its distribution in the body as specified by the International Commission on Radiological Units and Measurements (ICRU).

(k) "Rem" means the unit of dose equivalent from ionizing radiation to the total body or any internal organ or organ system. A "millirem (mrem)" is 1/1000 of a rem.

(l) "Picocurie (pCi)" means that quantity of radioactive material producing 2.22 nuclear transformations per minute.

(m) "Gross alpha particle activity" means the total radioactivity due to alpha particle emission as inferred from measurements on a dry sample.

(n) "Man-made beta particle and photon emitters" means all radionuclides emitting beta particles and/or photons listed in Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air or Water for Occupational Exposure, NBS Handbook 69, except the daughter products of thorium-232, uranium-235 and uranium-238.

(o) "Gross beta particle activity" means the total radioactivity due to beta particle emission as inferred from measurements on a dry sample.

(p) "Halogen" means one of the chemical elements chlorine, bromine or iodine.

(q) "Trihalomethane" (THM) means one of the family of organic compounds, named as derivatives of methane, wherein three of the four hydrogen atoms in methane are each substituted by a halogen atom in the molecular structure.

(r) "Total trihalomethanes" (TTHM) means the sum of the concentration in milligrams per liter of the trihalomethane compounds (trichloromethane [chloroform], dibromochloromethane, bromodichloromethane and tribromomethane [bromoform]), rounded to two significant figures.

(s) "Maximum Total Trihalomethane Potential (MTP)" means the maximum concentration of total trihalomethanes produced in a given water containing a disinfectant residual after 7 days at a temperature of 25° C or above.

(t) "Disinfectant" means any oxidant, including but not limited to chlorine, chlorine dioxide, chloramines, and ozone added to water in any part of the treatment or distribution process, that is intended to kill or inactivate pathogenic microorganisms.

§ 141.3 Coverage.

This part shall apply to each public water system, unless the public water system meets all of the following conditions:

(a) Consists only of distribution and storage facilities (and does not have any collection and treatment facilities);

(b) Obtains all of its water from, but is not owned or operated by, a public water system to which such regulations apply;

(c) Does not sell water to any person; and

(d) Is not a carrier which conveys passengers in interstate commerce.

§ 141.4 Variances and exemptions.

Variances or exemptions from certain provisions of these regulations may be granted pursuant to Sections 1415 and 1416 of the Act by the entity with primary enforcement responsibility. Provisions under Part 142, *National Interim Primary Drinking Water Regulations Implementation*—subpart E (Variances) and subpart F (Exemptions)—apply where EPA has primary enforcement responsibility.

§ 141.5 Siting requirements.

Before a person may enter into a financial commitment for or initiate construction of a new public water system or increase the capacity of an existing public water system, he shall notify the State and, to the extent practicable, avoid locating part or all of the new or expanded facility at a site which:

(a) Is subject to a significant risk from earthquakes, floods, fires or other disasters which could cause a breakdown of the public water system or a portion thereof; or

(b) Except for intake structures, is within the floodplain of a 100-year flood or is lower than any recorded high tide where appropriate records exist.

The U.S. Environmental Protection Agency will not seek to override land use decisions affecting public water systems siting which are made at the State or local government levels.

§ 141.6 Effective dates.

(a) Except as provided in paragraph (b) of this section, the regulations set forth in this part shall take effect on June 24, 1977.

(b) The regulations for total trihalomethanes set forth in § 141.12(c) shall take effect 2 years after the date of promulgation of these regulations for community water systems serving 75,000 or more individuals, and 4 years after the date of promulgation for communities serving 10,000 to 74,999 individuals.

(c) The regulations set forth in 141.11 (a), (c) and (d); 141.14(a)(1); 141.14(b)(1)(c); 141.14(b)(2)(i); 141.14(d); 141.21 (a), (c) and (i); 141.22 (a) and (e); 141.23 (a)(3) and (a)(4); 141.23(f); 141.24(a)(3); 141.24 (e) and (f); 141.25(e); 141.27(a); 141.28 (a) and (b); 141.31 (a), (c), (d) and (e); 141.32(b)(3); and 141.32(d) shall take effect immediately upon promulgation.

(d) The regulations set forth in 141.41 shall take effect 18 months from the date of promulgation. Suppliers must complete the first round of sampling and reporting within 12 months following the effective date.

(e) The regulations set forth in 141.42 shall take effect 18 months from the date of promulgation. All requirements in 141.42 must be completed within 12 months following the effective date.

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Subpart B—Maximum Contaminant Levels

§ 141.11 Maximum contaminant levels for inorganic chemicals.

(a) The MCL for nitrate is applicable to both community water systems and non-community water systems except as provided by in paragraph (d). The levels for *the other organic chemicals apply* only to community water systems. Compliance with MCLs for inorganic chemicals is calculated pursuant to § 141.23.

(b) The following are the maximum contaminant levels for inorganic chemicals other than fluoride:

Contaminant	*Level, milligrams per liter*
Arsenic	0.05
Barium	1.
Cadmium	0.010
Chromium	0.05
Lead	0.05
Mercury	0.002
Nitrate (as N)	10.
Selenium	0.01
Silver	0.05

(c) When the annual average of the maximum daily air temperatures for the location in which the community water system is situated is the following, the maximum contaminant levels for fluoride are:

Temperature Degrees Fahrenheit	Degrees Celsius	Level, milligrams per liter
53.7 and below	12.0 and below	2.4
53.8 to 58.3	12.1 to 14.6	2.2
58.4 to 63.8	14.7 to 17.6	2.0
63.9 to 70.6	17.7 to 21.4	1.8
70.7 to 79.2	21.5 to 26.2	1.6
79.3 to 90.5	26.3 to 32.5	1.4

(c) Fluoride at optimum levels in drinking water has been shown to have beneficial effects in reducing the occurrence of tooth decay.

(d) At the discretion of the State, nitrate levels not to exceed 20 mg/l may be allowed in a non-community water system if the supplier of water demonstrates to the satisfaction of the State that:

(1) Such water will not be available to children under 6 months of age; and

(2) There will be continuous posting of the fact that nitrate levels exceed 10 mg/l and the potential health effects of exposure; and

(3) Local and State public health authorities will be notified annually of nitrate levels that exceed 10 mg/l; and

(4) No adverse health effects shall result.

§ 141.12 Maximum contaminant levels for organic chumicals.

The following are the maximum contaminant levels for organic chemicals. The maximum contaminant levels for organic chemicals in paragraphs (a) and (b) of this section apply to all community water systems. *Compliance with the maximum* contaminant levels in paragraphs (a) and (b) is calculated pursuant to § 141.24. The maximum comtaminant level for total trihalomethanes in paragraph (c) of this section applies only to community water systems which serve a population of 10,000 or more individuals and which add a disinfectant (oxidant) to the water in any part of the drinking water treatment process. Compliance with the maximum contaminant level for total trihalomethanes is calculated pursuant to § 141.30.

	Level, milligrams per liter
(a) Chlorinated hydrocarbons:	
Endrin (1,2,3,4,10, 10-hexachloro-6,7-epoxy-1,4, 4a,5,6,7,8,8a-octahydro-1,4-endo, endo-5,8 - dimethano naphthalene).	0.0002
Lindane (1,2,3,4,5,6-hexachlorocyclohexane, gamma isomer).	0.004
Methoxychlor (1,1,1-Trichloro-2, 2 - bis [p-methoxyphenyl] ethane).	0.1
Toxaphene ($C_{10}H_{10}Cl_8$-Technical chlorinated camphene, 67–69 percent chlorine).	0.005
(b) Chlorophenoxys:	
2,4 - D, (2,4-Dichlorophenoxyacetic acid).	0.1
2,4,5-TP Silvex (2,4,5-Trichlorophenoxypropionic acid).	0.01

(c) Total trihalomethanes (the sum of the concentrations of bromodichloromethane, dibromochloromethane, tribromomethane (bromoform) and trichloromethane (chloroform)) 0.10 mg/l.

§ 141.13 Maximum contaminant levels for turbidity.

The maximum contaminant levels for turbidity are applicable to both community water systems and non-community water systems using surface water sources in whole or in part. The maximum contaminant levels for turbidity in drinking water, measured at a representative entry point(s) to the distribution system, are:

(a) One turbidity unit (TU), as determined by a monthly average pursuant to § 141.22, except that five or fewer turbidity units may be allowed if the supplier of water can demonstrate to the State that the higher turbidity does not do any of the following:

(1) Interfere with disinfection;

(2) Prevent maintenance of an effective disinfectant agent throughout the distribution system; or

(3) Interfere with microbiological determinations.

(b) Five turbidity units based on an average for two consecutive days pursuant to § 141.22.

§ 141.14 Maximum microbiological contaminant levels.

The maximum contaminant levels for coliform bacteria, applicable to community water systems and non-community water systems, are as follow

(a) When the membrane filter technique pursuant to § 141.21(a) is used, the number of coliform bacteria shall not exceed any of the following:

(1) One per 100 milliliters as the arithmetic mean of all samples examined per compliance period pursuant to § 141.21(b) or (c), except that, at the primacy Agency's discretion systems required to take 10 or fewer samples per month may be authorized to exclude one positive routine sample per month from the monthly calculation if: (i) as approved on a case-by-case basis the State determines and indicates in writing to the public water system that no unreasonable risk to health existed under the conditions of this modification. This determination should be based upon a number of factors not limited to the following: (A) the system provided and had maintained an active disinfectant residual in the distribution system, (B) the potential for contamination as indicated by a sanitary survey, and (C) the history of the water quality at the public water system (e.g. MCL or monitoring violations); (ii) the supplier initiates a check sample on each of two consecutive days from the same sampling point within 24 hours after notification that the routine sample is positive, and each of these check samples is negative; and (iii) the original positive routine sample is reported and recorded by the supplier pursuant to § 141.31(a) and § 141.33(a). The supplier shall report to the State its compliance with the conditions specified in this paragraph and a summary of the corrective action taken to resolve the prior positive sample result. If a positive routine sample is not used for the monthly calculation, another routine sample must be analyzed for compliance purposes. This provision may be used only once during two consecutive compliance periods.

(2) Four per 100 milliliters in more than one sample when less than 20 are examined per month; or

(3) Four per 100 milliliters in more than five percent of the samples when 20 or more are examined per month.

(b)(1) When the fermentation tube method and 10 milliliter standard portions pursuant to § 141.21(a) are used, coliform bacteria shall not be present in any of the following:

(i) More than 10 percent of the portions (tubes) in any one month pursuant to § 141.21 (b) or (c) except that, at the State's discretion, systems required to take 10 or fewer samples per month may be authorized to exclude on positive routine sample resulting in one or more positive tubes per month from the monthly calculation if: (A) as approved on a case-by-case basis the State determines and indicates in writing to the public water system that

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no unreasonable risk to health existed under the conditions of this modification. This determination should be based upon a number of factors not limited to the following: (*1*) the system provided and had maintained an active disinfectant residual in the distribution system, (*2*) the potential for contamination as indicated by a sanitary survey, and (*3*) the history of the water quality at the public water system (e.g. MCL or monitoring violations); (B) the supplier initiates a check sample on each of two consecutive days from the sampling point within 24 hours after notification that the routine sample is positive, and each of these check samples is negative; and (C) the original positive routine sample is reported and recorded by the supplier pursuant to § 141.31(a) and § 141.33(a). The supplier shall report to the State its compliance with the conditions specified in this paragraph and report the action taken to resolve the prior positive sample result. If a positive routine sample is not used for the monthly calculation, another routine sample must be analyzed for compliance purposes. This provision may be used only once during two consecutive compliance periods.

(ii) three or more portions in more than one sample when less than 20 samples are examined per month; or

(iii) three or more portions in more than five percent of the samples when 20 or more samples are examined per month.

(2) When the fermentation tube method and 100 milliliter standard portions pursuant to § 141.21(a) are used, coliform bacteria shall not be present in any of the following:

(i) More than 60 percent of the portions (tubes) in any month pursuant to § 141.21 (b) or (c), except that, State discretion, systems required to take 10 or fewer samples per month may be authorized to exclude one positive routine sample resulting in one or more positive tubes per month from the monthly calculation if: (A) as approved on a case-by-case basis the State determines and indicates in writing to the public water system that no unreasonable risk to health existed under the conditions of this modification. This determination should be based upon a number of factors not limited to the following: (*1*) the system provided and had maintained an active disinfectant residual in the distribution system, (*2*) the potential for contamination as indicated by a sanitary survey, and (iii) the history of the water quality at the public water system (e.g. MCL or monitoring violations); (B) the supplier initiates two consecutive daily check samples from the same sampling point within 24 hours after notification that the routine sample is positive, and each of these check samples is negative: and (C) the original positive routine sample is reported and recorded by the supplier pursuant to § 141.31(a) and § 141.33(a). The supplier shall report to the State its compliance with the conditions specified in this paragraph and a summary of the corrective action taken to resolve the prior positive sample result. If a positive routine sample is not used for the monthly calculation, another routine sample must be analyzed for compliance purposes. This provision may be used only once during two consecutive compliance periods.

(ii) five portions in more than one sample when less than five samples are examined per month: or

(iii) five portions in more than 20 percent of the samples when five or more samples are examined per month.

(c) For community or non-community systems that are required to sample at a rate of less than 4 per month, compliance with paragraphs (a), (b)(1), or (b)(2) of this section shall be based upon sampling during a 3 month period, except that, at the discretion of the State, compliance may be based upon sampling during a one-month period.

(d) If an average MCL violation is caused by a single sample MCL violation, then the case shall be treated as one violation with respect to the public notification requirements of § 141.32.

§ 141.15 Maximum contaminant levels for radium-226, radium-228, and gross alpha particle radioactivity in community water systems.

The following are the maximum contaminant levels for radium-226, radium-228, and gross alpha particle radioactivity:

(a) Combined radium-226 and radium-228—5 pCi/1.

(b) Gross alpha particle activity (including radium-226 but excluding radon and uranium)—15 pCi/1.

§ 141.16 Maximum contaminant levels for beta particle and photon radioactivity from man-made radionuclides in community water systems.

(a) The average annual concentration of beta particle and photon radioactivity from man-made radionuclides in drinking water shall not produce an annual dose equivalent to the total body or any internal organ greater than 4 millirem/year.

(b) Except for the radionuclides listed in Table A, the concentration of man-made radionuclides causing 4 mrem total body or organ dose equivalents shall be calculated on the basis of a 2 liter per day drinking water intake using the 168 hour data listed in "*Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air or Water for Occupational Exposure*," NBS Handbook 69 as amended August 1963, U.S. Department of Commerce. If two or more radionuclides are present, the sum of their annual dose equivalent to the total body or to any organ shall not exceed 4 millirem/year.

TABLE A.—*Average annual concentrations assumed to produce a total body or organ dose of 4 mrem/yr*

Radionuclide	Critical organ	pCi per liter
Tritium	Total body	20,000
Strontium-90	Bone marrow	8

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Subpart C—Monitoring and Analytical Requirements

§ 141.21 Microbiological contaminant sampling and analytical requirements.

(a) Suppliers of water for community and non-community water systems shall analyze or use the services of an approved laboratory for coliform bacteria to determine compliance with § 141.14. Analyses shall be conducted in accordance with the analytical recommendations set forth in "Standard Methods for the Examination of Water and Wastewater," American Public Health Association, 14th Edition, Method 908A, Paragraphs 1, 2 and 3—pp. 916–918; Method 908D, Table 908: I—p. 923; Method 909A, pp. 928–935, or "Microbiological Methods for Monitoring the Environment, Water and Wastes," U.S. EPA, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio 45268—EPA–600/8–78–017, December 1978. Available from ORD Publications, CERI, U.S. EPA, Cincinnati, Ohio 45268. Part III, Section B 1.0 through 2.6.2, pp. 108–112; 2.7 through 2.7.2(c), pp. 112–113; Part III, Section B 4.0 through 4.6.4(c), pp. 114–118, except that a standard sample size shall be employed. The standard sample used in the membrane filter procedure shall be 100 milliliters. The standard sample used in the 5 tube most probable number (MPN) procedure (fermentation tube method) shall be 5 times the standard portion. The standard portion is either 10 milliliters or 100 milliliters as described in § 141.14 (b) and (c). The samples shall be taken at points which are representative of the conditions within the distribution system.

(b) The supplier of water for a community water system shall take coliform density samples at regular time intervals, and in number proportionate to the population served by the system. In no event shall the frequency be less than as set forth below:

Population served:	*Minimum number of samples per month*
25 to 1,000	1
1,001 to 2,500	2
2,501 to 3,300	3
3,301 to 4,100	4
4,101 to 4,900	5
4,901 to 5,800	6
5,801 to 6,700	7
6,701 to 7,600	8
7,601 to 8,500	9
8,501 to 9,400	10
9,401 to 10,300	11
10,301 to 11,100	12
11,101 to 12,000	13
12,001 to 12,900	14
12,901 to 13,700	15
13,701 to 14,600	16
14,601 to 15,500	17
15,501 to 16,300	18
16,301 to 17,200	19
17,201 to 18,100	20
18,101 to 18,900	21
18,901 to 19 800	22
19,801 to 20,700	23
20,701 to 21,500	24
21,501 to 22,300	25
22,301 to 23,200	26
23,201 to 24,000	27
24,001 to 24,900	28
24,901 to 25,000	29
25,001 to 28,000	30

28,001 to 33,000	35
33,001 to 37,000	40
37,001 to 41,000	45
41,001 to 46,000	50
46,001 to 50,000	55
50,001 to 54,000	60
54,001 to 59,000	65
59,001 to 64,000	70
64,001 to 70,000	75
70,001 to 76,000	80
76,001 to 83,000	85
83,001 to 90,000	90
90,001 to 96,000	95
96,001 to 111,000	100
111,001 to 130,000	110
130,001 to 160,000	120
160,001 to 190,000	130
190,001 to 220,000	140
220,001 to 250,000	150
250,001 to 290,000	160
290,001 to 320,000	170
320,001 to 360,000	180
360,001 to 410,000	190
410,001 to 450,000	200
450,001 to 500,000	210
500,001 to 550,000	220
550,001 to 600,000	230
600,001 to 660,000	240
660,001 to 720,000	250
720,001 to 780,000	260
780,001 to 840,000	270
840,001 to 910,000	280
910,001 to 970,000	290
970,001 to 1,050,000	300
1,050,001 to 1,140,000	310
1,140,001 to 1,230,000	320
1,230,001 tc 1,320,000	330
1,320,001 to 1,420,000	340
1,420,001 to 1,520,000	350
1,520,001 to 1,630,000	360
1,630,001 to 1,730,000	370
1,730,001 to 1,850,000	380
1,850,001 to 1,970,000	390
1,970,001 to 2,060,000	400
2,060,001 to 2,270,000	410
2,270,001 to 2,510,000	420
2,510,001 to 2,750,000	430
2,750,001 to 3,020,000	440
3,020,001 to 3,320,000	450
3,320,001 to 3,620,000	460
3,620,001 tc 3,960,000	470
3,960,001 to 4,310,000	480
4,310,001 to 4,690,000	490
4,690,001 or more	500

Based on a history of no coliform bacterial contamination and on a sanitary survey by the State showing the water system to be supplied solely by a protected ground water source and free of sanitary defects, a community water system serving 25 to 1,000 persons, with written permission from the State, may reduce this sampling frequency except that in no case shall it be reduced to less than one per quarter.

(c) The supplier of water for a non-community water system shall be responsible for sampling coliform bacteria in each calendar quarter that the system provides water to the public. Such sampling shall begin within two years after promulgation. The State can adjust the monitoring frequency on the basis of a sanitary survey, the existence of additional safeguards such as a protective and enforced well code, or accumulated analytical data. Such frequency shall be confirmed or modified on the basis of subsequent surveys or data. The frequency shall not be reduced until the non-community water system has performed at least one coliform analysis of its drinking water and shown to be in compliance with § 141.14.

(d) (1) When the coliform bacteria in a single sample exceed four per 100 milliliters (§ 141.14(a)), at least two consecutive daily check samples shall be collected and examined from the same sampling point. Additional check samples shall be collected daily, or at a frequency established by the State, until the results obtained from at least two consecutive check samples show less than one coliform bacterium per 100 milliliters.

(2) When coliform bacteria occur in three or more 10 ml portions of a single sample (§ 141.14(b)(1)), at least two consecutive daily check samples shall be collected and examined from the same sampling point. Additional check samples shall be collected daily, or at a frequency established by the State, until the results obtained from at least two consecutive check samples show no positive tubes.

(3) When coliform bacteria occur in all five of the 100 ml portions of a single sample (§ 141.14(b)(2)), at least two daily check samples shall be collected and examined from the same sampling point. Additional check samples shall be collected daily, or at a frequency established by the State, until the results obtained from at least two consecutive check samples show no positive tubes.

(4) The location at which the check samples were taken pursuant to paragraphs (d) (1), (2), or (3) of this section shall not be eliminated from future sampling without approval of the State. The results from all coliform bacterial analyses performed pursuant to this subpart, except those obtained from check samples and special purpose samples, shall be used to determine compliance with the maximum contaminant level for coliform bacteria as established in § 141.14. Check samples shall not be included in calculating the total number of samples taken each month to determine compliance with § 141.21 (b) or (c).

(e) When the presence of coliform bacteria in water taken from a particular sampling point has been confirmed by any check samples examined as directed in paragraphs (d) (1), (2), or (3) of this section, the supplier of water shall report to the State within 48 hours.

(f) When a maximum contaminant level set forth in paragraphs (a), (b) or (c) of § 141.14 is exceeded, the supplier of water shall report to the State and notify the public as prescribed in § 141.31 and § 141.32.

(g) Special purpose samples, such as those taken to determine whether disinfection practices following pipe placement, replacement, or repair have been sufficient, shall not be used to determine compliance with § 141.14 or § 141.21 (b) or (c).

(h) A supplier of water of a community water system or a non-community water system may, with the approval of the State and based upon a sanitary survey, substitute the use of chlorine residual monitoring for not more than 75 percent of the samples required to be taken by paragraph (b) of this section, *Provided*, That the supplier of water takes chlorine residual samples at points which are representative of the conditions within the distribution system at the frequency of at least four for each substituted microbiological sample. There shall be at least daily determinations of chlorine residual. When the supplier of water exercises the option provided in this paragraph (h) of this section, he shall maintain no less than 0.2 mg/1 free chlorine throughout the public water distribution system. When a particular sampling point has been shown to have a free chlorine residual less than 0.2 mg/1, the water at that location shall be retested as soon as practicable and in any event within one hour. If the original analysis is confirmed, this fact shall be reported to the State within 48 hours. Also, if the analysis is confirmed, a sample for coliform bacterial analysis must be collected from that sampling point as soon as practicable and preferably within one hour, and the results of such analysis reported to the State within 48 hours after the results are known to the supplier of water. Analyses for residual chlorine shall be made in accordance with "Standard Methods for the Examination of Water and Wastewater," 13th Ed., pp. 129–132. Compliance with the maximum contaminant levels for coliform bacteria shall be determined on the monthly mean or quarterly mean basis specified in § 141.14, including those samples taken as a result of failure to maintain the required chlorine residual level. The State may withdraw its approval of the use of chlorine residual substitution at any time.

(i) The State has the authority to determine compliance or initiate enforcement action based upon analytical results or other information compiled by their sanctioned representatives and agencies.

§ 141.22 Turbidity sampling and analytical requirements.

(a) Samples shall be taken by suppliers of water for both community and non-community water systems at a representative entry point(s) to the water distribution system at least once per day, for the purpose of making turbidity measurements to determine compliance with § 141.13. If the State determines that a reduced sampling frequency in a non-community system will not pose a risk to public health, it can reduce the required sampling frequency. The option of reducing the turbidity frequency shall be permitted only in those public water systems that practice disinfection and which maintain an active residual disinfectant in the distribution system, and in those cases where the State has indicated in writing that no unreasonable risk to health existed under the circumstances of this option. The turbidity measurements shall be made by the Nephelometric Method in accordance with the recommendations set forth in "Standard Methods for Examination of Water and Wastewater," American Public Health Association, 14th Edition pp. 132–134; or Method 180.1.1-Nephrometric Method.

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(b) If the result of a turbidity analysis indicates that the maximum allowable limit has been exceeded, the sampling and measurement shall be confirmed by resampling as soon as practicable and preferably within one hour. If the repeat sample confirms that the maximum allowable limit has been exceeded, the supplier of water shall report to the State within 48 hours. The repeat sample shall be the sample used for the purpose of calculating the monthly average. If the monthly average of the daily samples exceeds the maximum allowable limit, or if the average of two samples taken on consecutive days exceeds 5 TU, the supplier of water shall report to the State and notify the public as directed in § 141.31 and § 141.32.

(c) Sampling for non-community water systems shall begin within two years after the effective date of this part.

(d) The requirements of this § 141.22 shall apply only to public water systems which use water obtained in whole or in part from surface sources.

(e) The State has the authority to determine compliance or initiate enforcement action based upon analytical results or other information compiled by their sanctioned representatives and agencies.

§ 141.23 Inorganic chemical sampling and analytical requirements.

(a) Analyses for the purpose of determining compliance with § 141.11 are required as follows:

(1) Analyses for all community water systems utilizing surface water sources shall be completed within one year following the effective date of this part. These analyses shall be repeated at yearly intervals.

(2) Analyses for all community water systems utilizing only ground water sources shall be completed within two years following the effective date of this part. These analyses shall be repeated at three-year intervals.

(3) For non-community water systems, whether supplied by surface or ground sources, analyses for nitrate shall be completed by December 24, 1980. These analyses shall be repeated at intervals determined by the State.

(4) The State has the authority to determine compliance or initiate enforcement action based upon analytical results and other information compiled by their sanctioned representatives and agencies.

(b) If the result of an analysis made pursuant to paragraph (a) indicates that the level of any contaminant listed in § 141.11 exceeds the maximum contaminant level, the supplier of water shall report to the State within 7 days and initiate three additional analyses at the same sampling point within one month.

(c) When the average of four analyses made pursuant to paragraph (b) of this section, rounded to the same number of significant figures as the maximum contaminant level for the substance in question, exceeds the maximum contaminant level, the supplier of water shall notify the State pursuant to § 141.31 and give notice to the public pursuant to § 141.32. Monitoring after public notification shall be at a frequency designated by the State and shall continue until the maximum contaminant level has not been exceeded in two successive samples or until a monitoring schedule as a condition to a variance, exemption or enforcement action shall become effective.

(d) The provisions of paragraphs (b) and (c) of this section notwithstanding, compliance with the maximum contaminant level for nitrate shall be determined on the basis of the mean of two analyses. When a level exceeding the maximum contaminant level for nitrate is found, a second analysis shall be initiated within 24 hours, and if the mean of the two analyses exceeds the maximum contaminant level, the supplier of water shall report his findings to the State pursuant to § 141.31 and shall notify the public pursuant to § 141.32.

(e) For the initial analyses required by paragraph (a)(1), (2) or (3) of this section, data for surface waters acquired within one year prior to the effective date and data for ground waters acquired within 3 years prior to the effective date of this part may be substituted at the discretion of the State.

(f) Analyses conducted to determine compliance with § 141.11 shall be made in accordance with the following methods:

(1) Arsenic—Method[1] 206.2, Atomic Absorption Furnace Technique; or Method[1] 206.3, or Method[4] D2972–78A, or Method[2] 301.A VII, pp. 159–162, or Method[3] I–1062–78, pp. 61–63, Atomic Absorption—Gaseous Hydride; or Method[1] 206.4, or Method[4] D–2972–78A, or Method[2] 404–A and 404–B(4), Spectrophotometric, Silver Diethyldithiocarbamate.

(2) Barium—Method[1] 208.1, or Method[2] 301–A IV, pp. 152–155, Atomic Absorption—Direct Aspiration; or Method[1] 208.2, Atomic Absorption Furnace Technique.

(3) Cadmium—Method[1] 213.1, or Method[4] 3557–78A or B, or Method[2] 301–A II or III, pp. 148–152, Atomic Absorption—Direct Aspiration; or Method[1] 213.2, Atomic Absorption Furnace Technique.

(4) Chromium—Method[1] 218.1, or Method[4] D–1687–77D, or Method[2] 301–A II or III, pp. 148–152, Atomic Absorption—Direct Aspiration; or Chromium—Method[1] 218.2, Atomic Absorption Furnace Technique.

(5) Lead—Method[1] 239.1, or Method[4] D–3559–78A or B, or Method[2] 301–A II or III, pp. 148–152, Atomic Absorption—Direct Aspiration; or Method[1] 239.2, Atomic Absorption Furnace Technique.

(6) Mercury—Method[1] 245.1, or Method[4] D–3223–79, or Method[2] 301–A VI, pp. 156–159, Manual Cold Vapor Technique; or Method[1] 245.2, Automated Cold Vapor Technique.

(7) Nitrate—Method[1] 352.1, or Method[4] D–992–71, or Method[2] 419–D, pp. 427–429, Colorimetric Brucine; or Method[1] 353.3, or Method[4] D–3867–79B, or Method[2] 419–C, pp. 423–427, Spectrometric, Cadmium Reduction; Method[1] 353.1, Automated Hydrazine Reduction; or Method[1] 353.2, or Method[4] D–3867–79A, or Method[2] 605, pp. 620–624, Automated Cadmium Reduction.

(8) Selenium—Method[1] 270.2, Atomic Absorption Technique; or Method[1] 270.3; or Method[3] I–1667–78, pp. 237–239, or Method[4] D–3859–79, or Method[2] 301–A VII, pp. 159–162, Hydride Generation—Atomic Absorption Spectrophotometry.

(9) Silver—Method[1] 272.1, or Method[2] 301–A II, Atomic Absorption—Direct Aspiration; or Method[1] 272.2, Atomic Absorption Techniques Furnace Technique.

(10) Fluoride—Electrode Method, or SPADNS Method, Method[2] 414–B and C, pp. 391–394, or Method[1] 340.1, "Colorimetric SPADNS with Bellack Distillation," or Method[1] 340.2, "Potentimetric Ion Selective Electrode;" or ASTM Method[4] D1179–72; or Colorimetric Method with Preliminary Distillation, Method[2] 603, Automated Complexone Method (Alizarin Fluoride Blue) pp. 614–616; or Automated Electrode Method, "Fluoride in Water and Wastewater," Industrial Method #380–75WE, Technicon Industrial Systems, Tarrytown, New York 10591, February 1976, or "Fluoride in Water and Wastewater Industrial Method #129–71W," Technicon Industrial Systems, Tarrytown, New York 10591, December 1972; or Fluoride, Total, Colorimetic, Zirconium—Eriochrome Cyanine R Method[3]—I–3325–78, pp. 365–367.

§ 141.24 Organic chemicals other than total trihalomethanes, sampling and analytical requirements.

(a) An analysis of substances for the purpose of determining compliance with § 141.12(a) and § 141.12(b) shall be made as follows:

(1) For all community water systems utilizing surface water sources, analyses shall be completed within one year following the effective date of this part. Samples analyzed shall be collected during the period of the year designated by the State as the period when contamination by pesticides is most likely to occur. These analyses shall be repeated at intervals specified by the State but in no event less frequently than at three year intervals.

(2) For community water systems utilizing only ground water sources, analyses shall be completed by those systems specified by the State.

(3) The State has the authority to determine compliance or initiate enforcement action based upon analytical results and other information compiled by their sanctioned representatives and agencies.

(b) If the result of an analysis made pursuant to paragraph (a) of this section indicates that the level of any contaminant listed in § 141.24 (a) and (b)

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exceeds the maximum contaminant level, the supplier of water shall report to the State within 7 days and initiate three additional analyses within one month.

(c) When the average of four analyses made pursuant to paragraph (b) of this section, rounded to the same number of significant figures as the maximum contaminant level for the substance in question, exceeds the maximum contaminant level, the supplier of water shall report to the State pursuant to § 141.31 and give notice to the public pursuant to § 141.32. Monitoring after public notification shall be at a frequency designated by the State and shall continue until the maximum contaminant level has not been exceeded in two successive samples or until a monitoring schedule as a condition to a variance, exemption or enforcement action shall become effective.

(d) For the initial analysis required by paragraph (a) (1) and (2) of this section, data for surface water acquired within one year prior to the effective date of this part and data for ground water acquired within three years prior to the effective date of this part may be substituted at the discretion of the State.

(e) Analysis made to determine compliance with § 141.12(a) shall be made in accordance with "Methods for Organochlorine Pesticides and Chlorophenoxy Acid Herbicides in Drinking Water and Raw Source Water," available from ORD Publications, CERI, EPA, Cincinnati, Ohio 45268; or "Organochlorine Pesticides in Water," 1977 Annual Book of ASTM Standards, part 31, Water, Method D3088; or Method 509–A, pp. 555–565; [2] or Gas Chromatographic Methods for Analysis of Organic Substances in Water,[3] USGS, Book 5, Chapter A–5, pp. 24–39.

(f) Analysis made to determine compliance with § 141.12(b) shall be conducted in accordance with "Methods for Organochlorine Pesticides and Chlorophenoxy Acid Herbicides in Drinking Water and Raw Source Water," available from ORD Publications, CERI, EPA, Cincinnati, Ohio 45268; or "Chlorinated Phenoxy Acid Herbicides in Water," 1977 Annual Book of ASTM Standards, part 31, Method D3478; or Method 509–B, pp. 555–5692; [2] or Gas Chromatographic Methods for Analysis of Organic Substances in Water,[5] USGS, Book 5, Chapter A–3, pp. 24–39.

§ 141.25 Analytical Methods for Radioactivity.

(a) The methods specified in *Interim Radiochemical Methodology for Drinking Water*, Environmental Monitoring and Support Laboratory, EPA–600/4–75–008, USEPA, Cincinnati, Ohio 45268, or those listed below, are to be used to determine compliance with §§ 141.15 and 141.16 (radioactivity) except in cases where alternative methods have been approved in accordance with § 141.27.

(1) Gross Alpha and Beta—Method 302 "Gross Alpha and Beta Radioactivity in Water" *Standard Methods for the Examination of Water and Wastewater*, 13th Edition, American Public Health Association, New York, N.Y., 1971.

(2) Total Radium—Method 304 "Radium in Water by Precipitation" Ibid.

(3) Radium-226—Method 305 "Radium-226 by Radon in Water" Ibid.

(4) Strontium-89,90 — Method 303 "Total Strontium and Strontium-90 in Water" Ibid.

(5) Tritium—Method 306 "Tritium in Water" Ibid.

(6) Cesium-134 — ASTM D–2459 "Gamma Spectrometry in Water," *1975. Annual Book of ASTM Standards, Water and Atmospheric Analysis*, Part 31, American Society for Testing and Materials, Philadelphia, PA. (1975).

(7) Uranium—ASTM D–2907 "Microquantities of Uranium in Water by Fluorometry," Ibid.

(b) When the identification and measurement of radionuclides other than those listed in paragraph (a) is required, the following references are to be used, except in cases where alternative methods have been approved in accordance with § 141.27.

(1) *Procedures for Radiochemical Analysis of Nuclear Reactor Aqueous Solutions*, H. L. Krieger and S. Gold, EPA–R4–73–014. USEPA, Cincinnati, Ohio, May 1973.

(2) *HASL Procedure Manual*, Edited by John H. Harley. HASL 300, ERDA Health and Safety Laboratory, New York, N.Y., 1973.

(c) For the purpose of monitoring radioactivity concentrations in drinking water, the required sensitivity of the radioanalysis is defined in terms of a detection limit. The detection limit shall be that concentration which can be counted with a precision of plus or minus 100 percent at the 95 percent confidence level (1.96σ where σ is the standard deviation of the net counting rate of the sample).

(1) To determine compliance with § 141.15 (a) the detection limit shall not exceed 1 pCi/l. To determine compliance with § 141.15(b) the detection limit shall not exceed 3 pCi/l.

(2) To determine compliance with § 141.16 the detection limits shall not exceed the concentrations listed in Table B.

TABLE B.—DETECTION LIMITS FOR MAN-MADE BETA PARTICLE AND PHOTON EMITTERS

Radionuclide	*Detection limit*
Tritium	1,000 pCi/l.
Strontium-89	10 pCi/l.
Strontium-90	2 pCi/l.
Iodine-131	1 pCi/l.
Cesium-134	10 pCi/l.
Gross beta	4 pCi/l.
Other radionuclides	1/10 of the applicable limit.

(d) To judge compliance with the maximum contaminant levels listed in sections 141.15 and 141.16, averages of data shall be used and shall be rounded to the same number of significant figures as the maximum contaminant level for the substance in question.

(e) The State has the authority to determine compliance or initiate enforcement action based upon analytical results or other information compiled by their sanctioned representatives and agencies.

§ 141.26 Monitoring Frequency for Radioactivity in Community Water Systems.

(a) Monitoring requirements for gross alpha particle activity, radium-226 and radium-228.

(1) Initial sampling to determine compliance with § 141.15 shall begin within two years of the effective date of these regulations and the analysis shall be completed within three years of the effective date of these regulations. Compliance shall be based on the analysis of an annual composite of four consecutive quarterly samples or the average of the analyses of four samples obtained at quarterly intervals.

(i) A gross alpha particle activity measurement may be substituted for the required radium-226 and radium-228 analysis *Provided*, That the measured gross alpha particle activity does not exceed 5 pCi/1 at a confidence level of 95 percent (1.65σ where σ is the standard deviation of the net counting rate of the sample). In localities where radium–228 may be present in drinking water, it is recommended that the State require radium–226 and/or radium–228 analyses when the gross alpha particle activity exceeds 2 pCi/1.

(ii) When the gross alpha particle activity exceeds 5 pCi/1, the same or an equivalent sample shall be analyzed for radium–226. If the concentration of radium–226 exceeds 3 pCi/1 the same or an equivalent sample shall be analyzed for radium–228.

(2) For the initial analysis required by paragraph (a)(1), data acquired within one year prior to the effective date of this part may be substituted at the discretion of the State.

(3) Suppliers of water shall monitor at least once every four years following the procedure required by paragraph (a)(1). At the discretion of the State, when an annual record taken in conformance with paragraph (a)(1) has established that the average annual concentration is less

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[1] "Methods of Chemical Analysis of Water and Wastes," EPA Environmental Monitoring and Support Laboratory, Cincinnati, Ohio 45268 (EPA–600/4–79–020), March 1979. Available from ORD Publications, CERI, EPA, Cincinnati, Ohio 45268. For approved analytical procedures for metals, the technique applicable to total metals must be used.

[2] "Standard Methods for the Examination of Water and Wastewater," 14th Edition, American Public Health Association, American Water Works Association, Water Pollution Control Federation, 1976.

[3] Techniques of Water—Resources Investigation of the United States Geological Survey, Chapter A–1, "Methods for Determination of Inorganic Substances in Water and Fluvial Sediments," Book 5, 1979, Stock #024–001–03177–9. Available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

[4] Annual Book of ASTM Standards, part 31 Water, American Society for Testing and Materials, 1976, Race Street, Philadelphia, Pennsylvania 19103.

[5] Techniques of Water—Resources Investigation of the United States Geological Survey, Chapter A–3, "Methods for Analysis of Organic Substances in Water," Book 5, 1972, Stock #2401–1227. Available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

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than half the maximum contaminant levels established by § 141.15, analysis of a single sample may be substituted for the quarterly sampling procedure required by paragraph (a)(1).

(i) More frequent monitoring shall be conducted when ordered by the State in the vicinity of mining or other operations which may contribute alpha particle radioactivity to either surface or ground water sources of drinking water.

(ii) A supplier of water shall monitor in conformance with paragraph (a)(1) within one year of the introduction of a new water source for a community water system. More frequent monitoring shall be conducted when ordered by the State in the event of possible contamination or when changes in the distribution system or treatment processing occur which may increase the concentration of radioactivity in finished water.

(iii) A community water system using two or more sources having different concentrations of radioactivity shall monitor source water, in addition to water from a free-flowing tap, when ordered by the State.

(iv) Monitoring for compliance with § 141.15 after the initial period need not include radium-228 *except when* required by the State, *Provided*, That the average annual concentration of radium-228 has been assayed at least once using the quarterly sampling procedure required by paragraph (a)(1).

(v) Suppliers of water shall conduct annual monitoring of any community water system in which the radium-226 concentration exceeds 3 pCi/1, when ordered by the State.

(4) If the average annual maximum contaminant level for gross alpha particle activity or total radium as set forth in § 141.15 is exceeded, the supplier of a community water system shall give notice to the State pursuant to § 141.31 and notify the public as required by § 141.32. Monitoring at quarterly intervals shall be continued until the annual average concentration no longer exceeds the maximum contaminant level or until a monitoring schedule as a condition to a variance, exemption or enforcement action shall become effective.

(b) Monitoring requirements for manmade radioactivity in community water systems.

(1) Within two years of the effective date of this part, systems using surface water sources and serving more than 100,000 persons and such other community water systems as are designated by the State shall be monitored for compliance with § 141.16 by analysis of a composite of four consecutive quarterly samples or analysis of four quarterly samples. Compliance with § 141.16 may be assumed without further analysis if the average annual concentration of gross beta particle activity is less than 50 pCi/1 and if the average annual concentrations of tritium and strontium-90 are less than those listed in Table A, *Provided*, That if both radionuclides are present the sum of their annual dose equivalents to bone marrow shall not exceed 4 millirem/year.

(i) If the gross beta particle activity exceeds 50 pCi/1, an analysis of the sample must be performed to identify the major radioactive constituents present and the appropriate organ and total body doses shall be calculated to determine compliance with § 141.16.

(ii) Suppliers of water shall conduct additional monitoring, as ordered by the State, to determine the concentration of man-made radioactivity in principal watersheds designated by the State.

(iii) At the discretion of the State, suppliers of water utilizing only ground waters may be required to monitor for man-made radioactivity.

(2) For the initial analysis required by paragraph (b)(1) data acquired within one year prior to the effective date of this part may be substituted at the discretion of the State.

(3) After the initial analysis required by paragraph (b)(1) suppliers of water shall monitor at least every four years following the procedure given in paragraph (b)(1).

(4) Within two years of the effective date of these regulations the supplier of any community water system designated by the State as utilizing waters contaminated by effluents from nuclear facilities shall initiate quarterly monitoring for gross beta particle and iodine-131 radioactivity and annual monitoring for strontium-90 and tritium.

(i) Quarterly monitoring for gross beta particle activity shall be based on the analysis of monthly samples or the analysis of a composite of three monthly samples. The former is recommended. If the gross beta particle activity in a sample exceeds 15 pCi/1, the same or an equivalent sample shall be analyzed for strontium-89 and cesium-134. If the gross beta particle activity exceeds 50 pCi/1, an analysis of the sample must be performed to identify the major radioactive constituents present and the appropriate organ and total body doses shall be calculated to determine compliance with § 141.16.

(ii) For iodine-131, a composite of five consecutive daily samples shall be analyzed once each quarter. As ordered by the State, more frequent monitoring shall be conducted when iodine-131 is identified in the finished water.

(iii) Annual monitoring for strontium-90 and tritium shall be conducted by means of the analysis of a composite of four consecutive quarterly samples or analysis of four quarterly samples. The latter procedure is recommended.

(iv) The State may allow the substitution of environmental surveillance data taken in conjunction with a nuclear facility for direct monitoring of manmade radioactivity by the supplier of water where the State determines such data is applicable to a particular community water system.

(5) If the average annual maximum contaminant level for man-made radioactivity set forth in § 141.16 is exceeded, the operator of a community water system shall give notice to the State pursuant to § 141.31 and to the public as required by § 141.32. Monitoring at monthly intervals shall be continued until the concentration no longer exceeds the maximum contaminant level or until a monitoring schedule as a condition to a variance, exemption or enforcement action shall become effective.

§ 141.27 Alternate analytical techniques.

(a) With the written permission of the State, concurred in by the Administrator of the U.S. EPA, an alternate analytical technique may be employed. An alternate technique shall be accepted only if it is substantially equivalent to the prescribed test in both precision and accuracy as it relates to the determination of compliance with any MCL. The use of the alternate analytical technique shall not decrease the frequency of monitoring required by this part.

§ 141.28 Approved laboratories.

(a) For the purpose of determining compliance with § 141.21 through § 141.27, samples may be considered only if they have been analyzed by a laboratory approved by the State except that measurements for turbidity, free chlorine residual, temperature and pH may be performed by any person acceptable to the State.

(b) Nothing in this Part shall be construed to preclude the State or any duly designated representative of the State from taking samples or from using the results from such samples to determine compliance by a supplier of water with the applicable requirements of this Part.

§ 141.29 Monitoring of consecutive public water systems.

When a public water system supplies water to one or more other public water systems, the State may modify the monitoring requirements imposed by this part to the extent that the interconnecion of the sysems jusifies treating them as a single system for monitoring purposes. Any modified monitoring shall be conducted pursuant to a schedule specified by the State and concurred in by the Administrator of the U.S. Environmental Protection Agency.

§ 141.30 Total trihalomethanes sampling, analytical and other requirements.

(a) Community water system which serve a population of 10,000 or more individuals and which add a disinfectant (oxidant) to the water in any part of the drinking water treatment process shall analyze for total trihalomethanes in accordance with this section. For systems serving 75,000 or more individuals, sampling and analyses shall begin not later than 1 year after the date of promulgation of this regulation. For systems serving 10,000 to 74,999

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individuals, sampling and analyses shall begin not later than 3 years after the date of promulgation of this regulation. For the purpose of this section, the minimum number of samples required to be taken by the system shall be based on the number of treatment plants used by the system, except that multiple wells drawing raw water from a single aquifer may, with the State approval, be considered one treatment plant for determining the minimum number of samples. All samples taken within an established frequency shall be collected within a 24-hour period.

(b)(1) For all community water systems utilizing surface water sources in whole or in part, and for all community water systems utilizing only ground water sources that have not been determined by the State to qualify for the monitoring requirements of paragraph (c) of this section, analyses for total trihalomethanes shall be performed at quarterly intervals on at least four water samples for each treatment plant used by the system. At least 25 percent of the samples shall be taken at locations within the distribution system reflecting the maximum residence time of the water in the system. The remaining 75 percent shall be taken at representative locations in the distribution system, taking into account number of persons served, different sources of water and different treatment methods employed. The results of all analyses per quarter shall be arithmetically averaged and reported to the State within 30 days of the system's receipt of such results. Results shall also be reported to EPA until such monitoring requirements have been adopted by the State. All samples collected shall be used in the computation of the average, unless the analytical results are invalidated for technical reasons. Sampling and analyses shall be conducted in accordance with the methods listed in paragraph (e) of this section.

(2) Upon the written request of a community water system, the monitoring frequency required by paragraph (b)(1) of this section may be reduced by the State to a minimum of one sample analyzed for TTHMs per quarter taken at a point in the distribution system reflecting the maximum residence time of the water in the system, upon a written determination by the State that the data from at least 1 year of monitoring in accordance with paragraph (b)(1) of this section and local conditions demonstrate that total trihalomethane concentrations will be consistently below the maximum contaminant level.

(3) If at any time during which the reduced monitoring frequency prescribed under this paragraph applies, the results from any analysis exceed 0.10 mg/l of TTHMs and such results are confirmed by at least one check sample taken promptly after such results are received, or if the system makes any significant change to its source of water or treatment program, the system shall immediately begin monitoring in accordance with the requirements of paragraph (b)(1) of this section, which monitoring shall continue for at least 1 year before the frequency may be reduced again. At the option of the State, a system's monitoring frequency may and should be increased above the minimum in those cases where it is necessary to detect variations of TTHM levels within the distribution system.

(c)(1) Upon written request to the State, a community water system utilizing only ground water sources may seek to have the monitoring frequency required by subparagraph (1) of paragraph (b) of this section reduced to a minimum of one sample for maximum TTHM potential per year for each treatment plant used by the system taken at a point in the distribution system reflecting maximum residence time of the water in the system. The system shall submit to the State the results of at least one sample analyzed for maximum TTHM potential for each treatment plant used by the system taken at a point in the distribution system reflecting the maximum residence time of the water in the system. The system's monitoring frequency may only be reduced upon a written determination by the State that, based upon the data submitted by the system, the system has a maximum TTHM potential of less than 0.10 mg/l and that, based upon an assessment of the local conditions of the system, the system is not likely to approach or exceed the maximum contaminant level for total TTHMs. The results of all analyses shall be reported to the State within 30 days of the system's receipt of such results. Results shall also be reported to EPA until such monitoring requirements have been adopted by the State. All samples collected shall be used for determining whether the system must comply with the monitoring requirements of paragraph (b) of this section, unless the analytical results are invalidated for technical reasons. Sampling and analyses shall be conducted in accordance with the methods listed in paragraph (e) of this section.

(2) If at any time during which the reduced monitoring frequency prescribed under paragraph (c)(1) of this section applies, the results from any analysis taken by the system for maximum TTHM potential are equal to or greater than 0.10 mg/l, and such results are confirmed by at least one check sample taken promptly after such results are received, the system shall immediately begin monitoring in accordance with the requirements of paragraph (b) of this section and such monitoring shall continue for at least one year before the frequency may be reduced again. In the event of any significant change to the system's raw water or treatment program, the system shall immediately analyze an additional sample for maximum TTHM potential taken at a point in the distribution system reflecting maximum residence time of the water in the system for the purpose of determining whether the system must comply with the monitoring requirements of paragraph (b) of this section. At the option of the State, monitoring frequencies may and should be increased above the minimum in those cases where this is necessary to detect variation of TTHM levels within the distribution system.

(d) Compliance with § 141.12(c) shall be determined based on a running annual average of quarterly samples collected by the system as prescribed in subparagraphs (1) or (2) of paragraph (b) of this section, If the average of samples covering any 12 month period exceeds the Maximum Contaminant Level, the supplier of water shall report to the State pursuant to § 141.31 and notify the public pursuant to § 141.32. Monitoring after public notification shall be at a frequency designated by the State and shall continue until a monitoring schedule as a condition to a variance, exemption or enforcement action shall become effective.

(e) Sampling and analyses made pursuant to this section shall be conducted by one of the following EPA approved methods:

(1) "The Analysis of Trihalomethanes in Drinking Waters by the Purge and Trap Method," Method 501.1, EMSL EPA Cincinnati, Ohio.

(2) "The Analysis of Trihalomethanes in Drinking Water by Liquid/Liquid Extraction,"Method 501.2, EMSL EPA Cincinnati, Ohio.

Samples for TTHM shall be dechlorinated upon collection to prevent further production of Trihalomethanes, according to the procedures described in the above two methods. Samples for maximum TTHM potential should not be dechlorinated, and should be held for seven days at 25° C prior to analysis.

(or above)

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according to the procedures described in the above two methods.

(f) Before a community water system makes any significant modifications to its existing treatment process for the purposes of achieving compliance with § 141.12(c), such system must submit and obtain State approval of a detailed plan setting forth its proposed modification and those safeguards that it will implement to ensure that the bacteriological quality of the drinking water served by such system will not be adversely affected by such modification. Each system shall comply with the provisions set forth in the State-approved plan. At a minimum, A State approved plan shall require the system modifying its disinfection practice to:

(1) Evaluate the water system for sanitary defects and evaluate the source water for biological quality;

(2) Evaluate its existing treatment practices and consider improvements that will minimize disinfectant demand and optimize finished water quality throughout the distribution system;

(3) Provide baseline water quality survey data of the distribution system. Such data should include the results from monitoring for coliform and fecal coliform bacteria, fecal streptococci, standard plate counts at 35° C and 20° C, phosphate, ammonia nitrogen and total organic carbon. Virus studies should be required where source waters are heavily contaminated with sewage effluent;

(4) Conduct additional monitoring to assure continued maintenance of optimal biological quality in finished water, for example, when chloramines are introduced as disinfectants or when pre-chlorination is being discontinued. Additional monitoring should also be required by the State for chlorate, chlorite and chlorine dioxide when chlorine dioxide is used as a disinfectant. Standard plate count analyses should also be required by the State as appropriate before and after any modifications;

(5) Consider inclusion in the plan of provisions to maintain an active disinfectant residual throughout the distribution system at all times during and after the modification.

Subpart D—Reporting, Public Notification and Record Keeping

§ 141.31 Reporting requirements.

(a) Except where a shorter period is specified in this part, the supplier of water shall report to the State the results of any test measurement or analysis required by this part within (A) the first ten days following the month in which the result is received or (B) the first ten days following the end of the required monitoring period as stipulated by the State, whichever of these is shortest.

(b) The supplier of water shall report to the State within 48 hours the failure to comply with any primary drinking water regulation (including failure to comply with monitoring requirements) set forth in this part.

(c) The supplier of water is not required to report analytical results to the State in cases where a State laboratory performs the analysis and reports the results to the State office which would normally receive such notification from the supplier.

(d) The water supply system, within ten days of completion of each public notification required pursuant to § 141.32, shall submit to the State a representative copy of each type of notice distributed, published, posted, and/or made available to the persons served by the system and/or to the media.

(e) The water supply system shall submit to the State within the time stated in the request copies of any records required to be maintained under § 141.33 hereof or copies of any documents then in existence which the State or the Administrator is entitled to inspect pursuant to the authority of § 1445 of the Safe Drinking Water Act or the equivalent provisions of State law.

§ 141.32 Public notification.

(a) If a community water system fails to comply with an applicable maximum contaminant level established in Subpart B, fails to comply with an applicable testing procedure established in Subpart C of this part, is granted a variance or an exemption from an applicable maximum contaminant level, fails to comply with the requirements of any schedule prescribed pursuant to a variance or exemption, or fails to perform any monitoring required pursuant to Section 1445 (a) of the Act, the supplier of water shall notify persons served by the system of the failure or grant by inclusion of a notice in the first set of water bills of the system issued after the failure or grant and in any event by written notice within three months. Such notice shall be repeated at least once every three months so long as the system's failure continues or the variance or exemption remains in effect. If the system issues water bills less frequently than quarterly, or does not issue water bills, the notice shall be made by or supplemented by another form of direct mail.

(b) If a community water system has failed to comply with an applicable maximum contaminant level, the supplier of water shall notify the public of such failure, in addition to the notification required by paragraph (a) of this section, as follows:

(1) By publication on not less than three consecutive days in a newspaper or newspapers of general circulation in the area served by the system. Such notice shall be completed within fourteen days after the supplier of water learns of the failure.

(2) By furnishing a copy of the notice to the radio and television stations serving the area served by the system. Such notice shall be furnished within seven days after the supplier of water learns of the failure.

(3) Except that the requirements of this subsection (b) may be waived by the State if it determines that the violation has been corrected promptly after discovery, the cause of the violation has been eliminated, and there is no longer a risk to public health.

(c) If the area served by a community water system is not served by a daily newspaper of general circulation, notification by newspaper required by paragraph (b) of this section shall instead be given by publication on three consecutive weeks in a weekly newspaper of general circulation serving the area. If no weekly or daily newspaper of general circulation serves the area, notice shall be given by posting the notice in post offices within the area served by the system.

(d) If a non-community water system fails to comply with an applicable MCL established in Subpart B of this part, fails to comply with an applicable testing procedure established in Subpart C of this part, is granted a variance or an exemption from an applicable MCL, fails to comply with the requirements of any schedule prescribed pursuant to a variance or exemption, or fails to perform any monitoring requirement pursuant to section 1445(a) of the Act, the supplier of water shall give notices by continuous posting of such failure or granting of a variance or exemption to the persons served by the system as long as the failure or granting of a variance or exemption continues. The form and manner for such notices shall be prescribed by the State and shall ensure that the public using the system is adequately informed of the failure or granting of the variance or exemption.

(e) Notices given pursuant to this section shall be written in a manner reasonably designed to inform fully the users of the system. The notice shall be conspicuous and shall not use unduly technical language, unduly small print or other methods which would frustrate the purpose of the notice. The notice shall disclose all material facts regarding the subject including the nature of the problem and, when appropriate, a clear statement that a primary drinking water regulation has been violated and any preventive measures that should be taken by the public. Where appropriate, or where

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designated by the State, bilingual notice shall be given. Notices may include a balanced explanation of the significance or seriousness to the public health of the subject of the notice, a fair explanation of steps taken by the system to correct any problem and the results of any additional sampling.

(f) Notice to the public required by this section may be given by the State on behalf of the supplier of water.

(g) In any instance in which notification by mail is required by paragraph (a) of this section but notification by newspaper or to radio or television stations is not required by paragraph (b) of this section, the State may order the supplier of water to provide notification by newspaper and to radio and television stations when circumstances make more immediate or broader notice appropriate to protect the public health.

§ 141.33 Record maintenance.

Any owner or operator of a public water system subject to the provisions of this part shall retain on its premises or at a convenient location near its premises the following records:

(a) Records of bacteriological analyses made pursuant to this part shall be kept for not less than 5 years. Records of chemical analyses made pursuant to this part shall be kept for not less than 10 years. Actual laboratory reports may be kept, or data may be transferred to tabular summaries, provided that the following information is included:

(1) The date, place, and time of sampling, and the name of the person who collected the sample;

(2) Identification of the sample as to whether it was a routine distribution system sample, check sample, raw or process water sample or other special purpose sample;

(3) Date of analysis;

(4) Laboratory and person responsible for performing analysis;

(5) The analytical technique/method used; and

(6) The results of the analysis.

(b) Records of action taken by the system to correct violations of primary drinking water regulations shall be kept for a period not less than 3 years after the last action taken with respect to the particular violation involved.

(c) Copies of any written reports, summaries or communications relating to sanitary surveys of the system conducted by the system itself, by a private consultant, or by any local, State or Federal agency, shall be kept for a period not less than 10 years after completion of the sanitary survey involved.

(d) Records concerning a variance or exemption granted to the system shall be kept for a period ending not less than 5 years following the expiration of such variance or exemption.

Subpart E—Special Monitoring Regulations for Organic Chemicals and Otherwise Unregulated Contaminants

§ 141.40 Special monitoring for organic chemicals.

(a) The Administrator may designate, by publication in the Federal Register, public water systems which are required to take water samples, provide information, and in appropriate cases analyze water samples for the purpose of providing information on contamination of drinking water sources and of treated water by organic chemicals.

(b) The Administrator shall provide to each public system designated pursuant to paragraph (a) of this section a written schedule for the sampling of source water or treated water by the system, with written instructions for the sampling methods and for handling of samples. The schedule may designate the locations or types of locations to be sampled.

(c) In cases where the public water system has a laboratory capable of analyzing samples for constituents specified by the Administrator, the Administrator may require analyses to be made by the public water system for submission to EPA. If the Administrator requires the analyses to be made by the public water system, he shall provide the system with written instructions as to the analytical procedures to be followed, or with references to technical documents describing the analytical procedures.

(d) Public water systems designated by the Administrator pursuant to paragraph (a) of this section shall provide to the Administrator, upon request, information to be used in the evaluation of analytical results, including records of previous monitoring and analyses, information on possible sources of contamination and treatment techniques used by the system.

§ 141.41 Special monitoring for sodium.

(a) Suppliers of water for community public water systems shall collect and analyze one sample per plant at the entry point of the distribution system for the determination of sodium concentration levels; samples must be collected and analyzed annually for systems utilizing surface water sources in whole or in part, and at least every three years for systems utilizing solely ground water sources. The minimum number of samples required to be taken by the system shall be based on the number of treatment plants used by the system, except that multiple wells drawing raw water from a single aquifer may, with the State approval, be considered one treatment plant for determining the minimum number of samples. The supplier of water may be required by the State to collect and analyze water samples for sodium more frequently in locations where the sodium content is variable.

(b) The supplier of water shall report to EPA and/or the State the results of the analyses for sodium within the first 10 days of the month following the month in which the sample results were received or within the first 10 days following the end of the required monitoring period as stipulated by the State, whichever of these is first. If more than annual sampling is required the supplier shall report the average sodium concentration within 10 days of the month following the month in which the analytical results of the last sample used for the annual average was received. The supplier of water shall not be required to report the results to EPA where the State has adopted this regulation and results are reported to the State. The supplier shall report the results to EPA where the State has not adopted this regulation.

(c) The supplier of water shall notify appropriate local and State public health officials of the sodium levels by written notice by direct mail within three months. A copy of each notice required to be provided by this paragraph shall be sent to EPA and/or the State within 10 days of its issuance. The supplier of water is not required to notify appropriate local and State public health officials of the sodium levels where the State provides such notices in lieu of the supplier.

(d) Analyses for sodium shall be performed by the flame photometric method in accordance with the procedures described in "Standard Methods for the Examination of Water and Wastewater," 14th Edition, pp. 250–253; or by Method 273.1, Atomic Absorption—Direct Aspiration or Method 273.2, Atomic Absorption—Graphite Furnace, in "Methods for Chemical Analysis of Water and Waste," EMSL, Cincinnati, EPA, 1979; or by Method D1428–64(a) in Annual Book of ASTM Standards, part 31, Water.

§ 141.42 Special monitoring for corrosivity characteristics.

(a) Suppliers of water for community public water systems shall collect samples from a representative entry point to the water distribution system for the purpose of analysis to determine the corrosivity characteristics of the water.

(1) The supplier shall collect two samples per plant for analysis for each plant using surface water sources wholly or in part or more if required by the State; one during mid-winter and one during mid-summer. The supplier of the water shall collect one sample per plant for analysis for each plant using ground water sources or more if required by the State. The minimum number of samples required to be taken by the system shall be based on the number of treatment plants used by the system, except that multiple wells drawing raw water from a single aquifer may, with the State approval, be considered one treatment plant for determining the minimum number of samples.

(2) Determination of the corrosivity characteristics of the water shall include measurement of pH, calcium hardness, alkalinity, temperature, total dissolved solids (total filterable residue), and calculation of the Langelier Index in accordance with paragraph (c) below. The determination of corrosivity characteristics shall only include one round of sampling (two samples per plant for surface water and one sample per plant for ground water sources). However, States may require more

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frequent monitoring as appropriate. In addition, States have the discretion to require monitoring for additional parameters which may indicate corrosivity characteristics, such as sulfates and chlorides. In certain cases, the Aggressive Index, as described in paragraph (c), can be used instead of the Langelier Index; the supplier shall request in writing to the State and the State will make this determination.

(b) The supplier of water shall report to EPA and/or the State the results of the analyses for the corrosivity characteristics within the first 10 days of the month following the month in which the sample results were received. If more frequent sampling is required by the State, the supplier can accumulate the data and shall report each value within 10 days of the month following the month in which the analytical results of the last sample was received. The supplier of water shall not be required to report the results to EPA where the State has adopted this regulation and results are reported to the State.

(c) Analyses conducted to determine the corrosivity of the water shall be made in accordance to the following methods:

(1) Langelier Index—"Standard Methods for the Examination of Water and Wastewater," 14th Edition, Method 203, pp. 61–63.

(2) Aggressive Index—"AWWA Standard for Asbestos-Cement Pipe, 4 in. through 24 in. for Water and Other Liquids." AWWA C400–77, Revision of C400–75, AWWA, Denver, Colorado.

(3) Total Filtrable Residue—"Standard Methods for the Examination of Water and Wastewater," 14th Edition, Method 208B, pp. 92–93; or "Methods for Chemical Analysis of Water and Wastes," Method 160.1.

(4) Temperature—"Standard Methods for the Examination of Water and Wastewater," 14th Edition, Method 212, pp. 125–126.

(5) Calcium hardness—EDTA Titrimetric Method "Standard Methods for the Examination of Water and Wastewater," 14th Edition, Method 309B, pp. 202–206; or "Annual Book of ASTM Standards," Method D1126–67 (8).

(6) Alkalinity—Methyl Orange and paint pH 4.5. "Standard Methods for the Examination of Water and Wastewater," 14th Edition, Method 403, pp. 278–281; or "Annual Book of ASTM Standards," Method D1067–70B; or "Methods for Chemical Analysis of Water and Wastes," Method 310.1.

(7) pH—"Standard Methods for the Examination of Water and Wastewater," 14th Edition, Method 424, pp. 460–465; or "Methods for Chemical Analysis of Water and Wastes," Method 150.1; or "Annual Book of ASTM Standards," Method D129378 A or B.

(8) Chloride—Potentiometric Method, "Standard Methods for the Examination of Water and Wastewater," 14th Edition, p. 306.

(9) Sulfate—Turbidimetric Method, "Methods for Chemical Analysis of Water and Wastes," pp. 277–278, EPA, Office of Technology Transfer, Washington, D.C. 20460, 1974, or "Standard Methods for the Examination of Water and Wastewater," 13th Edition, pp. 334–335, 14th Edition, pp. 496–498.

(d) Community water supply systems shall identify whether the following construction materials are present in their distribution system and report to the State:

- Lead from piping, solder, caulking, interior lining of distribution mains, alloys and home plumbing.
- Copper from piping and alloys, service lines, and home plumbing.
- Galvanized piping, service lines, and home plumbing.
- Ferrous piping materials such as cast iron and steel.
- Asbestos cement pipe.

In addition, States may require identification and reporting of other materials of construction present in distribution systems that may contribute contaminants to the drinking water, such as:

- Vinyl lined asbestos cement pipe.
- Coal tar lined pipes and tanks.

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